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

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Purpose: This systematic review aimed to report and explore the survival of dental veneers constructed from non-feldspathic porcelain over 5 and 10 years. ***Materials and Methods:*** A total of 4,294 articles were identified through a systematic search involving all databases in the Cochrane Library, MEDLINE (OVID), EMBASE, Web of Knowledge, specific journals (hand-search), conference proceedings, clinical trials registers, and collegiate contacts. Articles, abstracts, and gray literature were sought by two independent researchers. There were no language limitations. One hundred sixteen studies were identified for full-text assessment, with 10 included in the analysis (5 qualitative, 5 quantitative). Study characteristics and survival (Kaplan-Meier estimated cumulative survival and 95% confidence interval [CI]) were extracted or recalculated. A failed veneer was one which required an intervention that disrupted the original marginal integrity, had been partially or completely lost, or had lost retention more than twice. A meta-analysis and sensitivity analysis of Empress veneers was completed, with an assessment of statistical heterogeneity and publication bias. Clinical heterogeneity was explored for results of all veneering materials from included studies. ***Results:*** Within the 10 studies, veneers were fabricated with IPS Empress, IPS Empress 2, Cerinate, and Cerec computer-aided design/computer-assisted manufacture (CAD/CAM) materials VITA Mark I, VITA Mark II, Ivoclar ProCad. The meta-analysis showed the pooled estimate for Empress veneers to be 92.4% (95% CI: 89.8% to 95.0%) for 5-year survival and 66% to 94% (95% CI: 55% to 99%) for 10 years. Data regarding other non-feldspathic porcelain materials were lacking, with only a single study each reporting outcomes for Empress 2, Cerinate, and various Cerec porcelains over 5 years. The sensitivity analysis showed data from one study had an influencing and stabilizing effect on the 5-year pooled estimate. ***Conclusion:*** The long-term outcome (> 5 years) of non-feldspathic porcelain veneers is sparsely reported in the literature. This systematic review indicates that the 5-year cumulative estimated survival for etchable non-feldspathic porcelain veneers is over 90%. Outcomes may prove clinically acceptable with time, but evidence remains lacking and the use of these materials for veneers remains experimental. *Int J Prosthodont 2013;26:111–124. doi: 10.11607/ijp.3202*

The use of porcelain veneers for the esthetic restoration of malpositioned, malformed, and discolored teeth has become routine since their introduction in the early 1980s. Following fabrication from acrylic and composite resin materials, veneers began to be predictably bonded with feldspathic porcelains.

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Esthetically, veneers should be translucent enough to maximize light transmission but opaque enough to mask discolorations. The material should facilitate conservative tooth preparations. Handling should be straightforward during fabrication and clinical procedures. Micromechanically, it should be etchable to facilitate retention with the limited resistance form inherent with veneer preparations. It should be strong in tension and compression, and should maintain its marginal seal, luster, and shade over time.

Advances in porcelain and bonding technology have resulted in the development and marketing of an array of materials for the creation of porcelain veneers.

Castable glass-ceramics such as Dicor (Dentsply) and CerePearl became available in the early 1980s, but research revealed high failure rates, and their use

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.

decreased. Pressed ceramics such as IPS Empress (feldspathic porcelain with 40% to 55% leucite) (Ivoclar Vivadent) and Empress 2 (feldspathic porcelain with 70% volume lithium disilicate) became available in the 1990s. These materials are etchable and translucent. They are thicker than traditional feldspathic veneers, possibly necessitating a slightly deeper veneer preparation and more exposure of dentin.

Computer-aided design/computer-assisted manufacture (CAD/CAM) technologies became available around the start of the 21st century. These utilize many materials including the Cerec suite of porcelains (Sirona), Empress, and the new-and-improved IPS e.max Press (Ivoclar Vivadent). Ivoclar Vivadent advises that e.max has essentially the same composition as Empress 2, but was released in 2005 to reduce heterogeneity in manufacturing and success rates. CAD/CAM technology also utilizes polycrystalline ceramics such as Procera (Nobel Biocare) alumina and zirconia. Zirconia is non-etchable and not suitable for veneers. Alumina is also poorly etchable, but Nobel Biocare has espoused its use for veneers.

The traditional feldspathic veneers are highly esthetic, etchable, and extremely thin (facilitating conservative preparations). They are fiddly to handle and manufacturers and clinicians have been seeking an alternative material. The outcome of feldspathic porcelain veneers has been studied up to 21 years. A recent meta-analysis[1] found the summary cumulative survival was 95.7% (95% confidence interval [CI]: 92.9% to 98.4%) at 5 years, with post hoc analysis indicating that the 10-year best estimate might approach 95.6% (95% CI: 93.8% to 97.5%). Follow-up data points were limited at 10 years and beyond.

The clinical performance and survival of porcelain veneers made from non-feldspathic porcelain has not been summarized before. The individual studies of Empress veneers indicate that results for 5-year survival range from 76%[2] to 98%[3], but comprehensive knowledge of the outcomes of these and other non-porcelain veneers over time is limited.

This systematic review aimed to report and explore the survival of dental veneers constructed from non-feldspathic porcelain. It is part of a research project that systematically identified and appraised the outcome of dental laminate veneers constructed from various materials. It aimed to identify all relevant studies (published and unpublished) that followed at least some of the veneers for 5 years; calculate the overall best summary survival estimate where possible; examine sources of study heterogeneity that may impact this summary estimate; and explore aspects of the systematic review methods that may also impact this summary estimate.

Materials and Methods

Article Identification

All databases in 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 by keyword and by medical subject headings (MeSH) or Emtree. Keywords included "porcelain and veneer*" OR "dental and veneer*" OR "laminate* AND veneer*" OR "porcelain AND laminate*" OR "dental AND laminate*"; and the MeSH and Emtree terms included "DENTAL VENEERS." No keywords or MeSH terms were used to limit the search to human subjects or outcome studies. An example search is outlined in Table 1.

The journals *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* were hand-searched from January 2005 to June 2011. References of identified articles were examined for relevant studies.[4]

Unpublished data, abstracts, and gray literature were sought through clinical trials registers (Australian New Zealand Clinical Trials Registry, United States National Institutes of Health ClinicalTrials.gov, World Health Organization International Clinical Trials Registry Platform, European Union EU Clinical Trails Registry), conference proceedings, and by contacting academic colleagues. Articles in languages other than English were identified and translated, where necessary. Article identification, screening, 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 screening.

The results of the search are outlined in Fig 1. Inclusion criteria were human, prospective and

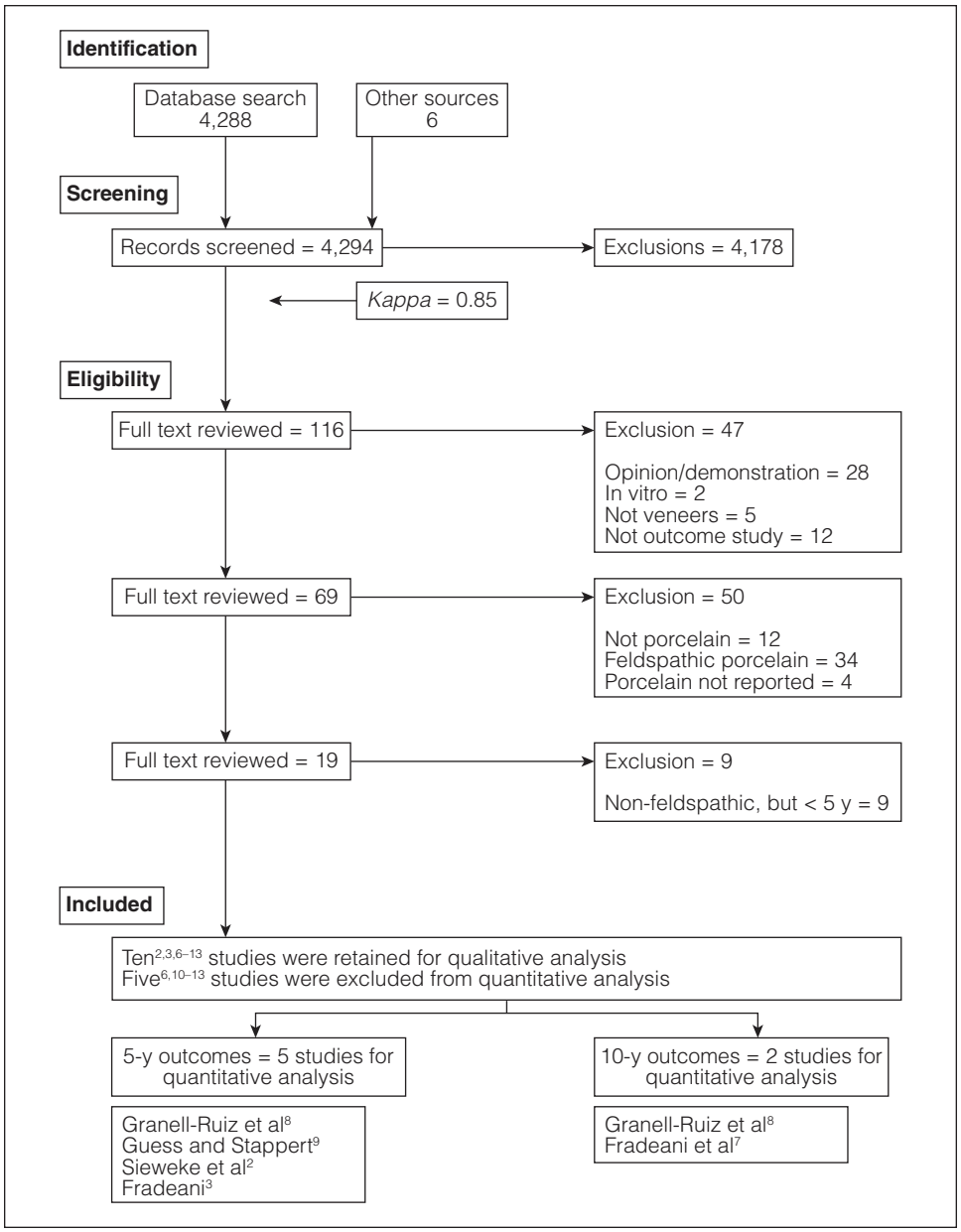


Fig 1 Flowchart of systematic search.

retrospective, and cohort and controlled trials assessing outcomes of non-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. Exclusion criteria were in vitro or laboratory studies, review and opinion articles, and studies reporting double data. Data on veneers with unusual designs, including no or extensive tooth preparation, were extracted from articles and excluded from recalculated results. Where necessary, the original authors were contacted to facilitate data extraction.[5] Articles assessing outcomes of veneers fabricated from the same material, where suitable data could be extracted, were retained for quantitative and qualitative analysis. Other relevant articles were retained for qualitative assessment.

Out 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 correlation). Of these, 69 clinical trials investigating dental laminate veneers were identified. Articles that were nonporcelain (n = 12), were feldspathic porcelain (n = 34), did not report porcelain type (n = 4), or followed non-feldspathic porcelain for less than 5 years (n = 9) were excluded.

Table 2 Summary of Study Characteristics of Articles Retained for Quantitative and Qualitative Analysis

Author	Study description
Fradeani[3]	Prospective cohort Follow-up: 6 y Inclusion period: 1991 to 1997 Language: English Sample: 83 veneers, 21 patients (age range: not reported), μ = 4.0 veneers/patient‡
Fradeani et al[7]	Retrospective cohort Follow-up: 12 y Inclusion period: 1991 to 2002 Language: English Sample: 182 veneers, 46 patients (age range: 19 to 66 y), μ = 4.0 veneers/patient‡ Two groups: 143 Empress veneers, 39 feldspathic veneers
Granell-Ruiz et al[8]	Retrospective cohort Follow-up: 11 y Inclusion period: 1995 to 2003 Language: English Sample: 323 veneers, 70 patients (age range: 18 to 74 y), μ = 4.6 veneers/patient‡ Two groups: 124 veneers (simple), 199 veneers (functional)
Guess and Stappert[9]	Prospective cohort Follow-up: 5 y (23 veneers observed up to 6 y) Inclusion period: 1999 to 2006 Language: English Sample: 66 veneers, 25 patients (age range: 19 to 64 y), μ = 2.6 veneers/patient‡ (range 1 to 6) Two groups: 42 veneers (overlap), 24 veneers (full)
Sieweke et al[2]	Retrospective cohort Follow-up: 6.5 y (1 veneer observed up to 7.9 y) Inclusion period: 1992 to 2000 Language: English Sample: 36 veneers, 17 patients (age range: 24 to 96 y), μ = 2.1 veneers/patient‡

*Kaplan-Meier estimated survival and 95% CI recalculated, as described in the text.
†Results reported as Kaplan-Meier estimated cumulative survival, with 95% CI estimated from in-text graph.
‡Mean not reported by the study and was estimated post hoc. This simple mean likely underestimates the true average.

Ten studies[2,3,6–13] were retained for qualitative analysis and five[2,3,7–9] were included in the quantitative meta-analysis. Two studies[9,10] included veneers with unusual preparations. For one study,[9] these veneers could be identified and separated from recalculated results. For the second study,[10] these veneers could not be separated and it was excluded from the meta-analysis. Two studies included veneers fabricated from multiple materials. The first[7] included both feldspathic and Empress veneers, and the outcomes could be extracted for each separately. The second[13] included many Cerec CAD/CAM materials, but the outcomes could not be separated and it was excluded from the meta-analysis. Two studies[11,12] published as abstracts did not report a cumulative survival or provide sufficient information to estimate the Kaplan-Meier cumulative survival or its standard error. The authors were contacted but were unable to provide supplementary information.

Within the 10 studies, veneers were fabricated with IPS Empress, leucite-reinforced glass-ceramic (5 studies), IPS Empress 2, lithium disilicate, modified feldspathic glass (1 study), Cerinate (DenMat) (3 studies), and Cerec CAD/CAM materials VITA Mark I, VITA Mark II, Ivoclar ProCad (1 study).

Other materials have been utilized to fabricate porcelain veneers. The following were identified during the systematic search, but did not fulfill the inclusion criteria for the review. Two studies reporting Dicor veneers (the longest study was conducted over 2.6 years with 38 veneers),[14] and one each reporting Procera aluminum oxide veneers (166 veneers, 53 patients, 4 years),[15] Finness All-Ceram (Dentsply) (26 veneers, 2 years),[16] and In-Ceram (Vident) (1 patient, 5 years).[17] No studies were identified of e.max (lithium disilicate) porcelain veneers. Of those materials, for which research is not included in this review, Procera and e.max remain in common use.

Characteristics and Reported Results of Articles Included in the Meta-Analysis

Five cohort studies reporting the outcome of IPS Empress porcelain veneers met the criteria for inclusion in the meta-analysis and qualitative review. Two

Design	Results
Setting: 1 operator, private practice, Italy Exclusions: not described Preparation design: preparations confined to enamel wherever possible, especially in the finishing area; proximal and palatal extensions as required Material: IPS Empress (leucite-reinforced glass-ceramic)	5 y: 98% (93% to 102%)* 6 y: 98% (93% to 102%)* 10 y: not available
Setting: no. of operators not reported, 2 private practices, Italy Exclusions: uncontrolled parafunction, periodontitis, severe gingival inflammation, poor oral hygiene, high caries rates Preparation design: incisal reduction up to 2 mm, labial reduction 0.3 to 0.6 mm cervically and 0.8 to 1.0 mm incisally Material: IPS Empress (leucite-reinforced glass-ceramic), feldspathic porcelain (vitadur alpha)	5 y: 97% (94% to 100%)* 10 y: 94% (88% to 99%)* 12 y: 94% (88% to 99%)* Feldspathic veneers (n = 39) excluded
Setting: multiple operators, university, Spain Exclusions: not reported; however, patients with parafunction, large composite restorations, less enamel were not excluded Preparation design: simple design (labial coverage) and functional design (incisal reduction, 1-mm palatal chamfer; 0.3- to 1-mm labial reduction) Material: IPS Empress (leucite-reinforced glass-ceramic)	5 y: 91% (87% to 94%)* 10 y: 66% (55% to 78%)* 11 y: 66% (55% to 78%)*
Setting: no. of operators not reported, university, Germany Exclusions: poor oral hygiene, high caries risk, parafunction, pronounced malocclusion, large cervical wedge-shaped defects, insufficient enamel quantity, existing root canal treatments Preparation design: overlapping incisal edge; full veneer, resembling ¾ crown; both included proximal surfaces and incisal reduction Material: IPS Empress (leucite-reinforced glass-ceramic)	5 y: 90% (77% to 103%)* 10 y: not available "Full" veneers (n = 24) excluded
Setting: 6 operators, university, Germany Inclusions: canine teeth only, healthy periodontium, nonrestored or carious teeth Preparation design: incisal lengthening (restore elements of canine guidance), oval groove in dentin, 1-mm reduction (all surfaces) Material: IPS Empress (leucite-reinforced glass-ceramic)	5 y: 76% (60% to 92%)† 6.5 y: 76% (60% to 92%)† 10 y: not available

were prospective studies, while three were retrospective. The number of patients ranged from 17 to 70, with a median of 25; while the number of veneers ranged from 36 to 323, with a median of 83. A rough average (estimated as the number of veneers divided by the number of patients) showed that patients each received between 2.1 and 4.6 veneers. All outcomes were assessed per veneer, with the effect of clustered results within a single patient not explored or accounted for during analysis. The study characteristics are summarized in Table 2.

The studies reported a range of outcomes. All reported complications and survival, and some also reported quality[3,7,9] (United States Public Health Service [USPHS],[18] California Dental Association [CDA][19]) and patient satisfaction.[8] Definitions of survival and its relationship to the severity of complications and impaired restorative quality differed across the studies. Four[2,7–9] included irreparable failures and loss of function as criteria for failure, while one[3] did not define failure or related entities. Additional criteria included endodontic complications,[9] secondary caries,[9] impaired esthetics,[7] and debonding.[2] One study also defined a category for relative failure,[9] which included minor fractures and restorations that were lost but could be rebonded. The criteria for impaired esthetics[7] was assessed via the CDA[19] criteria, with no study considering the patient's satisfaction with the appearance or comfort of the veneers.

For this systematic review, survival was defined according to the six-field criteria[20]: success, survival, dead, loss to follow-up, repaired, or failed (Table 3). A failed veneer was one that required an intervention that disrupted the original marginal integrity (eg, restoration to manage caries), had been partially or completely lost for any reason (eg, large fracture, tooth extraction), or had lost retention more than twice. Veneers in patients who died or became lost to follow-up were considered censored data. Successful, surviving, and repaired veneers were "survivals" for reporting purposes.

Where required, the following data with appropriately defined outcome measures were extracted from text and graphs: number of veneers in situ, number censored, number failed, and the timing of

Table 3 The Six-Field Classification System

Field	Definition
Successful	Success outcome was designated when review of documentation or patient examination revealed no evidence of retreatment other than maintenance procedures. These included professional prophylaxis and smoothing of minor porcelain chipping. Smoothing 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	Surviving outcome was designated when the patient was unable to be examined by the author, but either the referring dentist or the patient confirmed that there had been no retreatment other than that previously described for a successful outcome.
Unknown	Unknown outcome was designated when the patient could not be traced.
Dead	Any patient who had died during the survey period was placed in this category, irrespective of whether they had experienced successful or surviving treatment up until 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	The category retreatment was used when the patient had undergone any form of retreatment other than maintenance procedures as previously described. Occlusal or lingual perforations 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	This was designated when the original marginal integrity of the restorations and teeth was maintained.
Failed	This category was designated when part or all of the prosthesis had been lost, when the original marginal integrity of the restorations and teeth had been modified, or when the restoration had lost retention more than twice.

these outcomes. Life tables were constructed with yearly intervals. The cumulative estimated survival was calculated with the Kaplan-Meier[21] method, and the standard error was calculated with Greenwood's formula.

Sieweke and coworkers[2] reported the 6.5-year outcomes of 36 Empress veneers on canine teeth in 17 patients. Eight veneers fractured over the study period, with the remainders remaining bonded and in function. Unfortunately, the esthetic outcome was not reported in this study. The estimated cumulative survival was reported in text and graphically. The 95% CI was reported graphically, but it revealed a nonsymmetric confidence interval around the Kaplan-Meier point estimate. Digitization of the graph indicated an upper standard error of 7% and a lower standard error of 9%. Insufficient data regarding loss to follow-up and time in situ were provided to allow life table reconstruction and data recalculation. Therefore, the standard error was estimated to be 8%. The 5-year and 6.5-year estimated cumulative survivals used for this meta-analysis were 76% (95% CI: 60% to 92%).

Fradeani[3] reviewed the outcome of 83 Empress veneers in 21 patients over 6 years. A single veneer fractured at 5 years. The USPHS criteria revealed the remaining veneers as biologically stable, with acceptable marginal integrity and esthetic appearance. A bar graph representing the number of veneers in situ aided life table reconstruction. The 5- and 6-year estimated cumulative survivals were 98% (95% CI: 93% to 102%).

Fradeani published a second paper of outcomes of two types of veneers over 12 years with colleagues in 2005.[7] It is likely, but not specifically stated, that veneers included in the 1998 paper were also included in the 2005 paper. To reduce the impact of using these data twice in the meta-analysis, the 5-year outcomes were taken from Fradeani's 1998 paper, and the 10- to 12-year outcomes were taken from the 2005 paper.

This second paper included both Empress and feldspathic veneers. Of the 182 veneers, 143 were constructed from Empress. Five Empress veneers fractured, with the remainders considered survivors. Descriptions in the text and graphs aided life table reconstruction. The 10- and 12-year estimated cumulative survivals for Empress veneers were 94% (95% CI: 88% to 99%).

Guess and Stappert[9] reviewed the outcome of 66 Empress veneers fabricated with two different designs: the overlap (n = 42) and the full veneer (n = 24). The full veneer was extensive, resembling a three-quarter all ceramic crown. The authors provided sufficient data to allow its removal from their overall results, and the remaining veneers in this article met the inclusion criteria for the meta-analysis. Two failures occurred between 1.5 and 3 years, with one veneer suffering an extensive fracture, while another debonded and was lost. Seven other minor fractures occurred. The USPHS criteria revealed the veneers were biologically stable, with acceptable marginal integrity and esthetic appearance. Survival was reported up to 5 years, but an additional 15 veneers were observed up to 6 years. The authors did not specifically explain why survival was truncated at 5 years, but it likely related to concerns regarding data stability. The authors stated that future assessment

and reporting was planned. Together with text and tables, the 5-year estimated cumulative survival for the overlap veneer design was 91% (95% CI: 78% to 103%).

Granell-Ruiz and colleagues[8] reviewed the outcome of 323 Empress veneers over 3 to 11 years in an article published in Spanish and English. Veneers were also fabricated with two different designs: simple (labial reduction only) and functional (labial and incisal reduction, with a 1-mm palatal chamfer). Both designs were suitable for inclusion in the meta-analysis. Thirteen veneers fractured, 29 debonded, and 10 presented with carious margins. It was unclear whether the debonded veneers were able to be rebonded. For this systematic review, 52 of the 323 veneers were considered failures. This study also reported that two patients (with a rough average of 4.6 veneers each) were dissatisfied with their veneers. As this was the only study that reviewed patient satisfaction, these patient-related concerns were not considered failures. This resulted in an estimated cumulative survival at 5 years of 91% (95% CI: 87% to 94%) and at 10 and 11 years of 66% (95% CI: 55% to 78%). Additional complications and concerns with quality were also noted, including loss of vitality (n = 9), possibly transient sensitivity (n = 10), marginal staining (n = 127), and noticeable marginal defect (n = 8). The severity of these complications was difficult to ascertain in the translated article, but may have approximated a Bravo rating from the USPHS criteria. Thus, these were not considered additional failures.

Characteristics and Reported Results of Articles Included in the Qualitative Description

Five cohort studies reporting the outcome of IPS Empress 2,[6] Cerinate,[10–12] and Cerec[13] porcelain veneers met the inclusion criteria for the qualitative review. Four reported prospectively, while the remaining study did not classify its direction of inquiry. The number of patients ranged from 21 to 307, with a median of 30; while the number of veneers ranged from 115 to 736, with a median of 300. A rough average showed that patients each received between 2.3 and 10 veneers. The study characteristics are summarized in Table 4.

The article by Aykor and Ozel[6] reviewed the outcome of 300 veneers in 30 patients over 5 years. Each patient received 10 veneers, and thus many veneers were exposed to the same favorable or unfavorable environmental conditions within the same patient. Patients were randomly divided into two groups based on cementation: total-etch adhesive versus self-etch adhesive. The random allocation protocol was not discussed in the article. The quality of the veneers was reported with USPHS criteria for marginal adaption, marginal discoloration, secondary caries, gingival response, postoperative sensitivity, and shade satisfaction. All veneers, bonded with each adhesive, were clinically acceptable at 5 years.

The article by Wiedhahn et al[13] reported the outcome of 715 veneers fabricated with a Cerec CAD/CAM system for 307 patients. Two milling systems were used, with 329 veneers and 386 veneers milled with Cerec 1 and Cerec 2, respectively. Veneers were fabricated with a variety of porcelain materials (VITA Mark I, VITA Mark II, Ivoclar ProCad), but their distribution across each material was not reported. The operator used various veneer designs and also used the Cerec veneers to repair previously failed crowns, fixed partial dentures, and restorations (n = 108). Results were reported with USPHS criteria and estimated cumulative survival. Fourteen failures were reported by the authors, including fracture (n = 5), extraction (n = 6), and significant color dissatisfaction (n = 1). They also included two veneers that were changed to abutments for fixed dental prostheses as failures, but this category is considered censored for this systematic review. The authors also reported 63 veneers with cement excess or overhang, 2 with a marginal gap, and 4 with a distinct shoulder. Therefore, considering the 75 failures, the estimated cumulative survival at 5 and 9.5 years was 92% (95% CI: 89% to 94%) and 52% (95% CI: 39% to 65%), respectively.

The article by Shang and Mu[10] was translated from Chinese to English by the *Chinese Medical Journal*. It reported on 736 Cerinate veneers in 184 patients over 5 years. Veneers were bonded to both prepared and unprepared tooth surfaces, but the outcomes of these individual techniques could not be separated. The recall rate and censorship was not reported, but tabulations indicate that all veneers were followed for the entire study period. Twenty-eight veneers were reported as unsuccessful at 5 years, where failure included a broad range of mechanical, biologic, and esthetic complications. The estimated cumulative survival was not reported but was calculated for this review to be 96% (95% CI: 95% to 98%).

Two further studies were reported as abstracts by Strassler and Weiner[11,12] on the outcome of Cerinate porcelain veneers. The quality of the veneers was reported with truncated USPHS criteria for color, marginal adaption, and marginal discoloration only. The estimated cumulative survival was unreported and unable to be recalculated. The first study reviewed 115 veneers in 21 patients, reporting that 8 required replacement due to fracture over 7 to 10 years. The

Table 4 Summary of Study Characteristics of Articles Retained for Qualitative Analysis

Author	Study description
Aykor and Ozel[6]	Prospective cohort Follow-up: 5 y Inclusion period: 1991 to 1997 Language: English Sample: 300 veneers, 30 patients, 10 veneers/patient Two groups: 150 veneers, 15 patients, 10 veneers/patient Age range: 28 to 54 y
Shang and Mu[10]	Prospective cohort Follow-up: 5 y Inclusion period: Since 1996 Languages: Chinese and English Sample: 736 veneers, 184 patients (age range: 18 to 65 y), μ = 4 veneers/patient†
Strassler and Weiner[11]	Prospective cohort Follow-up: 10 y Inclusion period: not reported Language: English (abstract) Sample: 115 veneers, 21 patients (age not reported), μ = 5.5 veneers/patient†
Strassler and Weiner[12]	Prospective cohort Follow-up: 12.7 y Inclusion period: not reported Language: English (abstract) Sample: 196 veneers, 29 patients (age not reported), μ = 6.8 veneers/patient†
Wiedhahn et al[13]	Cohort study, direction of inquiry not reported Follow-up: 9 y Inclusion period: 1989 to 1999 Language: German and English Sample: 715 veneers, 307 patients (mean age: 43.9 ± 14.4 y), μ = 2.3 veneers/patient† Milling groups: 329 veneers (Cerec 1), 386 veneers (Cerec 2) Material: not reported

FPD = fixed partial denture; CAD/CAM = computer-aided design/computer-assisted manufacture.
*Results from article, reported as percentage or number. Time-to-event analysis (such as Kaplan-Meier) was not performed and could not be recalculated.
†Mean not reported by the study and was estimated post hoc. This simple mean likely underestimates the true average.
‡Kaplan-Meier estimated survival and 95% CI recalculated, as described in the text.

second reviewed 196 veneers in 29 patients, reporting that 7 required replacement and 10 presented with a significant marginal deficiency over 12.7 years. Loss to follow-up and censorship were not reported. It is also likely that some or all of the veneers reviewed in the first study were included in the second study, and thus present double data for this systematic review.

Despite identifying three studies regarding the outcomes of Cerinate porcelain veneers, the quality of reporting of two was insufficient to allow these outcomes to be included in a meta-analysis. Although these studies cannot be directly included in the meta-analysis, the reported outcomes provide further insight into the clinical performance of these materials when used for porcelain veneers.

Data Analysis

The estimated cumulative survival and associated standard error for each study reporting outcomes of Empress veneers at 5 and 10 years was considered for a meta-analysis. Cochran Q and associated *P* value were assessed to evaluate heterogeneity between the estimated cumulative survival of studies. This test has low power to detect homogeneity,[22] especially when there are few studies (as in this meta-analysis), and it was considered that $P < .10$ indicated the presence of statistical heterogeneity. In such circumstances, the random-effects meta-analytic method was used to calculate the pooled summary estimate and 95% CI. The I^2 statistic was calculated to evaluate the variation in the summary estimate that may be attributable to underlying heterogeneity (rather than chance), and a Galbraith plot was constructed to view the heterogeneity graphically.

A sensitivity analysis was completed to test the effect of underlying assumptions on the overall estimate. The influence of individual studies was assessed.

A funnel plot was constructed to investigate the possibility of publication bias or other biases associated with small studies. The Duval and Tweedie nonparametric trim and fill method[23] was used to explore missing hypothetical data. Stata version 11 statistical package (Stata) was used for the analyses.

Design	Results
Setting: no. of operators not reported, university, Turkey Exclusions: poor oral hygiene, extensive loss of tooth structure, excessive crowding, parafunction, periodontal problems, smokers Preparation design: supragingival cervical finishing line, incisal edge butt-joint, 0.75-mm labial reduction, 2 groups: total-etch adhesive and self-etch adhesive Material: IPS Empress 2 (lithium disilicate, modified feldspathic glass)	5 y: 98% (97% to 100%)‡ 10 y: not available
Setting: multiple operators, practice location not reported, China Inclusions: discolored (n = 503), damaged (n = 138), malaligned (n = 86), abnormal (n = 27) teeth Exclusions: not reported Preparation design: prepared and unprepared tooth surfaces Material: Cerinate	Recall rate not reported, but possibly 100% 5 y: 96% (95% to 98%)‡ 5 y: 3.8% "unsuccessful"*
Setting: not reported Exclusions: not reported Preparation design: not reported Material: Cerinate	Recall rate not reported, 100% retention rate* 8 veneers replaced*
Setting: not reported Exclusions: not reported Design: not reported Material: Cerinate	Recall rate not reported, 100% retention rate* 7 veneers replaced*
Setting: 1 operator, private practice, Germany Exclusions: not reported Preparation design: various designs including incisal reduction, proximal reduction, preparations overlaid retained restorations, severely discolored dentin covered with composite resin opaquer 108 veneers were bonded to previously failed crowns/FPDs/restorations Material: Cerec CAD/CAM system, multiple materials (VITA Mark I, VITA Mark II, Ivoclar ProCad)	5 y: 92% (89% to 94%)‡ 9.5 y: 52% (39% to 65%)‡ 10 y: not available

Results

5-year Results

The 5-year estimated cumulative survival for Empress veneers ranged from 76% to 98% across individual studies. Statistically, these results were not considered heterogenous (Cochran Q = 10.58, degree of freedom [*df*] 3, $P = .014$). However, approximately 70% of the variation in the individual study estimates was considered attributable to statistical heterogeneity ($I^2 = 71.2\%$), which suggests that the variations in the results are unlikely to be simply due to chance. The 5-year fixed effect pooled cumulative estimated survival was 92.4% (95% CI: 89.8% to 95.0%) (Fig 2).

The Galbraith plot (Fig 3) showed that the point estimate of two studies (Fradeani[3] and Sieweke et al[2]) was toward the outer boundary of 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 data from Granell-Ruiz et al[8] increased the summary estimate beyond the 95% CI of the original calculation. Of the four studies, these data have the tightest standard error of 1.7% and contribute 61% of the weight of the fixed effect pooled summary estimate. Removal redistributes the weighting of the remaining three studies, with the Fradeani[3] results now contributing 82% of the pooled estimate and increases the size of the survival estimate. Conversely, removal of Fradeani[3] data from the calculation decreases the summary estimate, but the recalculated outcome remains within the original 95% CI. Its removal, however, had the greatest effect on statistical heterogeneity, with a Cochran Q = 3.26, *df* 2, $P = .196$, and I^2 reduced to 39%. Data from Granell-Ruiz et al[8] has a stabilizing effect on the pooled estimate for the 5-year outcome of Empress veneers.

The funnel plot (Fig 5) showed that the studies were moderately well distributed around the point estimate. Statistical trimming and filling of the actual and hypothetical data points with the Duval and Tweedie nonparametric method[23] did not indicate missing data. However, any conclusions regarding publication

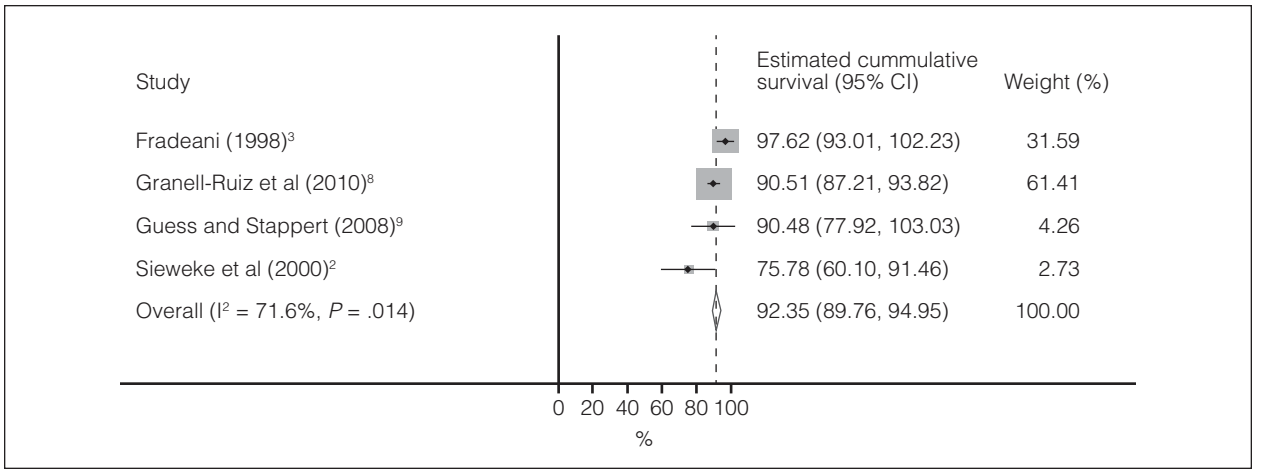


Fig 2 Forest plot of the 5-year estimated cumulative survival of Empress porcelain veneers. The fixed effects pooled estimate is 92.4% (95% CI: 89.8% to 95.0%, Cochran Q = 10.58, *df* 3, *P* < .014, I^2 = 71.6%).

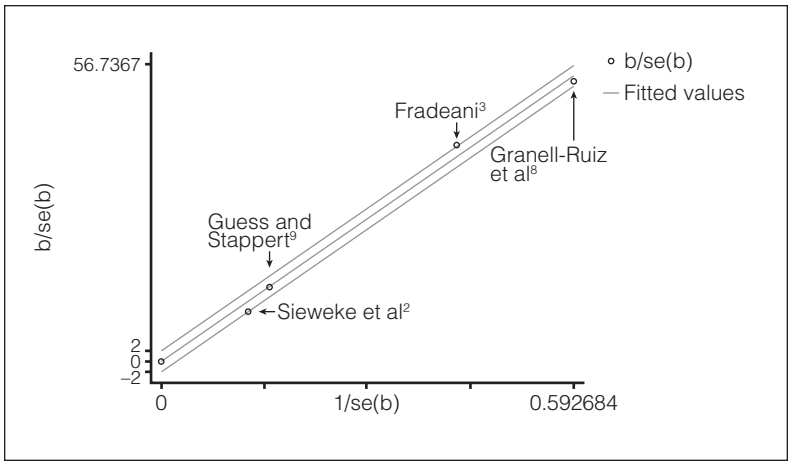
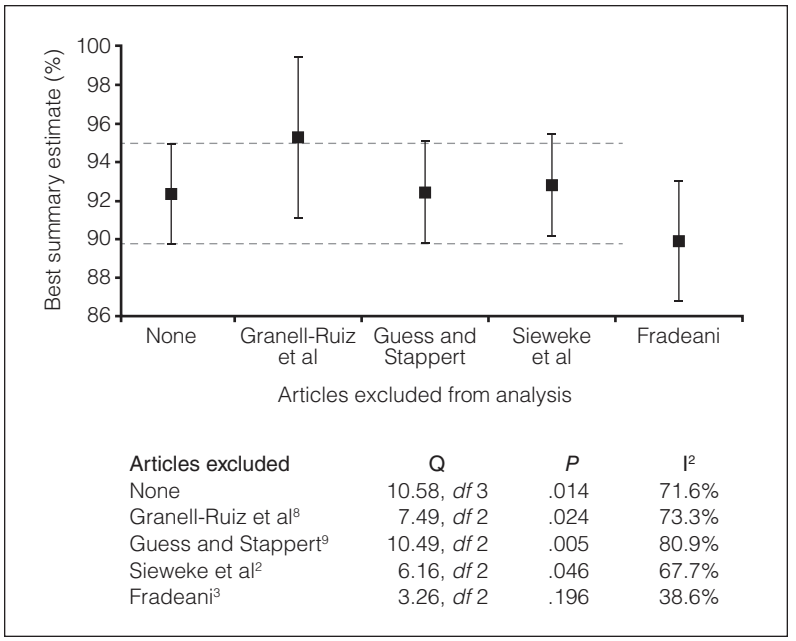


Fig 3 Galbraith plot showing the summary log cumulative survival included as a solid line banded by its 95% CI. The point estimate of two studies (Sieweke et al[2] and Fradeani[3]) is placed towards the outer boundary of the CI of the plotted statistic.



Articles excluded	Q	*P*	I^2
None	10.58, *df* 3	.014	71.6%
Granell-Ruiz et al[8]	7.49, *df* 2	.024	73.3%
Guess and Stappert[9]	10.49, *df* 2	.005	80.9%
Sieweke et al[2]	6.16, *df* 2	.046	67.7%
Fradeani[3]	3.26, *df* 2	.196	38.6%

Fig 4 Sensitivity analysis. Removal of one study (Granell-Ruiz et al[8]) increased the best summary estimate to 95.3% (95% CI: 91.1% to 99.46%) beyond that of the 95% CI of the original calculation.

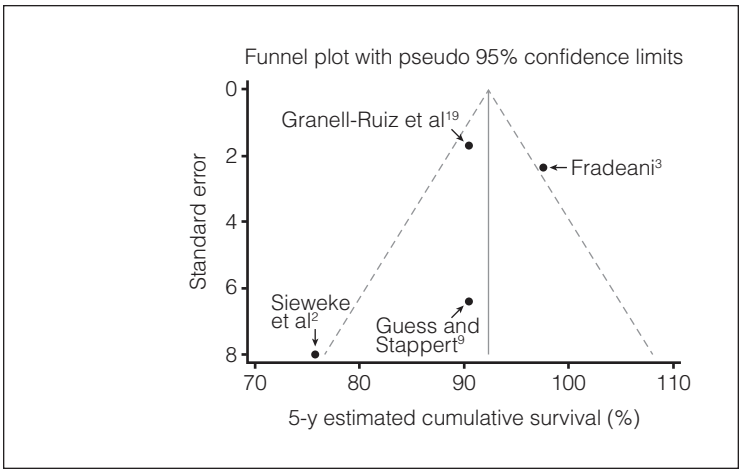


Fig 5 Funnel plot. Studies were moderately well distributed around the point estimate.

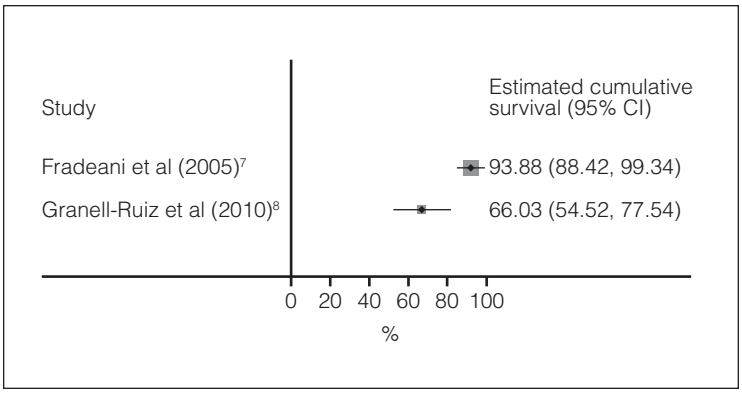


Fig 6 Forest plot to explore the 10-year estimated cumulative survival of empress porcelain veneers. Marked heterogeneity between studies is present (Cochran Q = 18.36, *df* 1, $P < .001$; $I^2 = 94.6\%$). The summary estimate was not pooled.

bias (or other small trial biases) drawn from four data points are weak.

The pooled estimate at 5 years for Empress veneers is similar to that found by the single studies reporting veneer outcomes of Empress 2[6] (95% [95% CI: 97% to 100%]), Cerinate[10] (96% [95% CI: 95% to 98%]), and various Cerec porcelains[13] (92% [95% CI: 89% to 94%]).

10-year Results

The 10-year estimated cumulative survivals were provided by two studies for Empress veneers. One study reported to 11 years, and the other to 12 years. The estimated cumulative survivals ranged from 66% to 94%, and the associated 95% CIs were as low as 55% and as high as 99%. These results were too disparate to calculate a pooled estimate (Cochran Q = 18.36, *df* 1, $P < .001$, $I^2 = 94.6\%$). The spread of the results can be seen on a forest plot (Fig 6).

The 9.5-year estimated cumulative survival for various Cerec porcelain veneers was 52% (95% CI: 39% to 65%).

Discussion

The long-term outcome (> 5 years) of non-feldspathic porcelain veneers remains uncertain because of the lack of sufficient follow-up beyond 5 years. The 5-year estimated cumulative survival for etchable non-feldspathic porcelain veneers was above 90%.

Systematic reviews are retrospective in nature and are reliant on the quality and quantity of previous research as well as the ability of the systematic reviewers to identify those published and unpublished studies. As with all systematic reviews, their results must be interpreted in light of the individual included studies. Each study differs by inclusion criteria, length of follow-up, loss to follow-up, clinical methodology, survival definitions, and other qualities. To reduce the

impact of these variations and allow readers to interpret the breadth of the results, the reviewers recalculated survival estimates based on a uniform definition and have reported the characteristics of the studies in detail.

The meta-analysis based on four studies showed the pooled estimate for 5-year survival of Empress veneers to be 92.4% (95% CI: 89.8% to 95.0%). Data regarding other non-feldspathic porcelain materials were lacking, with only a single study each reporting outcomes for Empress 2[6] (95% [95% CI: 97% to 100%]), Cerinate[10] (96% [95%CI: 95% to 98%]), and various Cerec porcelains[13] (92% [95% CI: 89% to 94%]) over 5 years. Regarding two other commonly used porcelain veneering materials, a study reported a 4-year estimated cumulative survival of 64% (no 95% CI) for Procera aluminium oxide veneers, and no data were found reporting the outcome of e.max veneers.

The authors' recent systematic review[1] for feldspathic porcelain veneers found a 5-year estimated cumulative survival of 95.7% (95% CI: 92.9% to 98.4%), and a post-hoc analysis revealed that the best estimate for 10-year survival might approach 95.6% (95% CI: 93.8% to 97.5%). Decreased survivals were observed when the enamel bonding structure was reduced, with veneers partially bonded to dentin or large retained restorations.

The present meta-analysis identified four studies that met the inclusion criteria and provided data that could contribute to the pooled survival estimate for Empress veneers. The weight each study contributes to the summary estimate is related to the precision of its results, which is related to its sample size. Therefore, studies with more precise estimates, as evidenced by a small standard error (and consequently a tight CI), contribute a greater weight to the overall estimate than studies with more variability in their results. The study with the tightest CI had the largest number of veneers (124 veneers), and the one with the widest CI had the smallest number of veneers (36 veneers). Therefore, the relative variation in results within each study is not surprising, with the largest precision associated with that study having the greatest power.

The sensitivity analysis where each study was sequentially removed from the meta-analysis revealed that the removal of one study (Granell-Ruiz et al[8]) changed the summary estimate beyond that of the expected 95% confidence range. This is possibly counterintuitive. One may expect that the removal of the study with the lowest survival would dramatically affect the results, but with the weighting method for the fixed effects meta-analysis, this does not occur. Use of a random effects method, however, would have quadrupled the weighting of the smallest study by Sieweke et al[2] from 3% to 12%. Despite this, in comparison with the 30% weighting of the two largest studies, the results remained essentially the same (random effects pooled estimate = 93% [95% CI: 88% to 98%]).

Even though one single study was exerting a high influence on the 5-year results for Empress veneers, this study had a stabilizing effect on the results and provided a more conservative estimate of the outcome than would have occurred if it did not exist.

Interestingly, as time progressed, the outcome of veneers within this large study altered dramatically.[8] The 10- and 11-year survivals were found to be 66% (95% CI: 55% to 78%). This outcome was recalculated for this meta-analysis, as described in the methods. It included 52 failures, rather than the reported 42. It could be argued that this recalculated cumulative survival was conservative. Eight additional "noticeable marginal defects" were reported by the authors. It was unclear whether these marginal defects were probeable or whether they were marked enough to affect gingival health or expose underlying dentine. Other papers had also reported "marginal defects," but classified these as a clinically acceptable presentation. Therefore, the authors decided not to include these additional complications, but to err on the side of statistical caution.

The second paper with 10-year results of Empress veneers[7] reported a high-survival rate of 94% (95% CI: 88% to 99%). This study was conducted in a private practice and reported strict exclusion criteria (uncontrolled parafunction, periodontitis with severe gingival inflammation, poor oral hygiene, high caries rate). In comparison with its counterpart, veneers in the first study were completed by multiple operators at a university clinic, where exclusions were minimal. The authors stated that patients with parafunction, teeth with large composite resin restorations, and teeth with reduced enamel structure were not excluded from the study.

The apparently contradictory outcomes of Empress veneers over the long term is likely related to the inclusion criteria. When veneers are placed in high-risk environments, such as those reported by Granell-Ruiz and colleagues,[8] they inevitably suffer a higher complication rate. The results from both studies are important to clinical decisions. Patients receiving veneers will invariably fall within the homogenous patient population treated by Fradeani's research group[7] or into the more heterogenous patient population treated by Granell-Ruiz's research group.[8] Despite the apparent disparity between the results, each result can be applied with care to a specific patient population to help estimate specific survival rates. It is therefore

accepted that while Empress veneers are possible restorative options in many situations, exposure to high-risk situations will result in a higher failure rate.

This observation is also supported by the 5-year outcome reported by Sieweke et al.[2] A 76% survival rate over 5 years appears low and initially would create concern regarding the clinical performance of the material. This study, however, placed veneers on canine teeth only, and they were specifically designed to restore canine guidance. While all care was taken with measurement of the posterior determinants of jaw function, the authors found that Empress veneers under such loads also exhibited a high, and arguably unacceptably high, failure rate.

The study completed by Guess and Stappert[9] followed the outcome of veneers fabricated to two different designs. The outcome of the overlap veneer was included in the meta-analysis (95% [95% CI: 77% to 103%]). The outcome of the "full veneer" was 100%, but was not eligible for this meta-analysis. This was essentially designed as a three-quarter crown, with resistance form. Veneer preparations vary between teeth, but even with an incisal overlap and palatal chamfer, veneers inherently lack resistance form. Comparing these different veneers is interesting: increasing the retention of the material (by increasing the resistance form) will likely improve the outcome. Therefore, other techniques to increase retention might also be expected to improve the outcome.

It is generally accepted that bonding veneers to ensure their retention is essential.[1,24,25] It is of concern, therefore, that some promote the use of aluminum oxide (Procera) for veneers. For example, Nobel Biocare's product information states that it can be used "in instances where you can respect its preparation requirements," but that it "must be bonded" with "dual cure resin cements using adhesive bonding techniques" that contain "phosphate bonded monomer-containing composites."[26]

Five-year outcomes for Procera alumina veneers were not available for this systematic review, but a group of researchers lead by Mounajjed[16] have reviewed the outcome of 166 veneers in 53 patients. They reported an estimated cumulative survival over 4 years of 64% (no 95% CI was available), despite veneers being bonded as recommended by the manufacturer. The researchers were concerned by this low survival rate and examined the etched surface of the alumina core under ×500 magnification. They discovered that the surface of the etched alumina core failed to demonstrate a roughness similar to that of etched feldspathic porcelain and concluded that this lack of microroughness probably contributed to the reduced survival.

Five-year outcomes for Cerinate porcelain veneers were available from one research group.[10] The high survival of 96% (95% CI: 95% to 98%) is encouraging, but it is unclear why less outcome data are available for this particular porcelain veneer. Cerinate has been in use since the early 1980s, and two longer studies following veneers over 7 years[11] and almost 13 years[12] were reported as abstracts in the late 1990s. Abstracts by definition are summaries of the research, and these lacked details regarding complications, failures, censorship, and loss to follow-up. Unfortunately, the research was not published as full papers, and the clinical performance of Cerinate veneers over the long term remains unknown.

A single study published outcomes of multiple types of Cerec veneers.[13] It included two types of milling machines and three types of porcelain. The researchers also bonded 108 of the veneers (15%) to previously failed prostheses (a non-enamel substrate). The 9.5-year cumulative survival rate was 52% (95% CI: 39% to 65%). The high numbers included (715 veneers in 307 patients) indicate that this study had sufficient power to report its outcome, and therefore this low survival is unlikely to be due to chance. The confusion between the numbers of veneers fabricated by the various techniques clouds the conclusions that can be drawn from this study. However, it would be reasonable to recommend that this technique for porcelain veneers should be used with caution.

Outcomes for lithium discilicate (Empress 2 and e.max) have also been sparsely published. IPS e.max has been available for less than 5 years, but it would be encouraging to see the outcomes of ongoing trials reported for the profession's appraisal. The only data regarding the material are in its previous form as Empress 2[6]. With tight exclusion criteria, Empress 2 veneers achieved a 5-year cumulative survival rate of 98% (95% CI: 97% to 100%). The study included 30 patients who each received 10 veneers. This is a high number of veneers present within the same environment (that is, in the same mouth). With the defined exclusion criteria, it is likely that all patients were low risk, thus increasing the chance that 10 surviving veneers would cluster within each patient. Given this methodology, it would be prudent to consider the results of this study as one outcome per patient, rather than one outcome per veneer. This would remove the cluster-related bias, and result in a study equivalent to 30 veneers (in 30 patients). This changes the apparent high power (secondary to the 300 veneers) to a more reasonable reduced power (related now to 30 veneers) and continued uncertainty of the clinical performance of lithium disilicate veneers.

It is accepted that the outcomes of veneers reported in other trials also suffered from cluster-related bias. Multiple veneers were placed within the same mouths, with a rough average indicating that patients each received between 2.1 and 6.8 veneers. Unfortunately, the studies did not report how many veneers each patient received, and also did not provide sufficient information to allow the outcomes to be recalculated, accounting for clustering.

Clearly, the long-term outcome (> 5 years) of non-feldspathic porcelain veneers is sparsely reported in the literature. The present systematic review indicates that the 5-year cumulative estimated survival for etchable non-feldspathic porcelain veneers is over 90%. Outcomes may prove clinically acceptable with time, but evidence remains lacking and the use of these materials for veneers remains experimental. Based on the evidence in the literature at this time, it would be difficult to justify the recommendation of a non-feldspathic veneer in a nonresearch setting and difficult to justify the current marketing tactics for these unproven materials. Clinician–researchers using these materials should review the performance of these veneers and report results to help support treatment decisions.

Conclusion

The 5-year estimated cumulative survival for etchable non-feldspathic porcelain veneers was above 90%. The meta-analysis based on four studies showed the pooled estimate for Empress veneers to be 92.4% (95% CI: 89.8% to 95.0%). The long-term outcome (> 5 years) of non-feldspathic porcelain veneers remains uncertain and the use of these materials for veneers remains experimental. Future outcome studies should report the complications, failures, censorship, and loss to follow-up with sufficient detail to facilitate meta-analyses to summarize the data and increase the power. Consideration should be given to clustered outcomes when reporting data so that proper account can be taken in the analyses.

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