The Up to 21-Year Clinical Outcome and Survival of Feldspathic Porcelain Veneers: Accounting for Clustering

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Purpose: This study aimed to investigate the clinical outcome and estimated cumulative survival rate of feldspathic porcelain veneers in situ for up to 21 years while also accounting for clustered outcomes. ***Materials and Methods:*** Porcelain veneers (n = 499) placed in patients (n = 155) by a single prosthodontist between 1990 and 2010 were sequentially included, with 239 veneers (88 patients) placed before 2001 and 260 veneers (67 patients) placed thereafter. Nonvital teeth, molar teeth, or teeth with an unfavorable periodontal prognosis were excluded. Preparations had chamfer margins, incisal reduction, palatal overlap, and at least 80% enamel. Feldspathic veneers from refractory dies were etched (hydrofluoric acid), silanated, and bonded. Many patients received more than 1 veneer (mean: 5.8 ± 4.3). Clustered outcomes were accounted for by randomly selecting (random table) 1 veneer per patient for analysis. Clinical outcome (success, survival, unknown, dead, repair, failure) and Kaplan-Meier estimated cumulative survival were reported. Differences in survival were analyzed using the log-rank test. ***Results:*** For the random sample of veneers (n = 155), the estimated cumulative survival rates were 96% ± 2% (10 years) and 96% ± 2% (20 years). For the entire sample, the survival rates were 96% ± 1% (10 years) and 91% ± 2% (20 years). Survival did not statistically differ between these groups (P = .65). Seventeen veneers in 8 patients failed, 75 veneers in 30 patients were classified as unknown, and 407 veneers in 130 patients survived. Multiple veneers in the same mouth experienced the same outcome, clustering the results. ***Conclusions:*** Multiple dental prostheses in the same mouth are exposed to the same local and systemic factors, resulting in clustered outcomes. Clustered outcomes should be accounted for during analysis. When bonded to prepared enamel substrate, feldspathic porcelain veneers have excellent long-term survival with a low failure rate. The 21-year estimated cumulative survival for feldspathic porcelain veneers bonded to prepared enamel was 96% ± 2%. *Int J Prosthodont 2012;25:604–612.*

A porcelain veneer is a thin bonded ceramic restoration used to restore the facial surface and part of the proximal surfaces of teeth.[1] Veneers allow for the conservative management of tooth misalignment (instant orthodontics), unesthetic shape and form, and discoloration.

Indirect laminate veneers were first described by Charles Pincus in 1937[2] as a temporary method to improve the tooth shapes of people in the film industry. The introduction of acid etching by Buonocore[3] and composite resins by Bowen[4] in the 1950s led to increased mainstream acceptance of the technique. In 1983, Simonsen and Calamia[5] published a laboratory study describing feldspathic porcelain laminate veneers retained by the acid-etch technique. That same year, Horn[6] published the first report of the clinical application of this method.

Feldspathic porcelain is a predominantly glassy ceramic based on a naturally occurring glass: feldspar. Feldspar primarily contains silica (silicon oxide) and alumina (aluminum oxide) but also boric oxide, potash (potassium oxide), and soda (sodium oxide).

Feldspathic porcelain has advantages and disadvantages. The platinum foil and refractory die fabrication methods are technique sensitive, and the resulting porcelain is eggshell thin and requires careful handling prior to bonding. The material is translucent, creating an extremely life-like restoration, but can be poor at masking darkened tooth structure. The extremely thin nature of the material allows for minimal tooth preparation, thus conserving enamel. Feldspathic porcelain is also etchable, which is an essential prerequisite for effective bonding to etched enamel.

Many materials have been used for the fabrication of porcelain laminate veneers over the last 30 years.

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A literature review that included studies in which feldspathic veneers were in situ for 5 years identified six studies[7–14] reporting Kaplan-Meier cumulative survival and two studies[15,16] reporting straight percentage outcomes. This literature review was completed as part of a larger systematic review.[17]

These feldspathic veneer studies included between 50[14] and 1,177[7] patients and between 87[11,12] and 3,255[16] veneers. Patients received between 1 and 20 veneers each. Ten-year Kaplan-Meier failure rates ranged from 5%[9] to 47%,[7] while 5-year Kaplan-Meier failure rates ranged from 2%[9] to 42%.[13] Clearly, these outcomes are not in agreement, and the apparently contradictory outcomes likely relate to differences in methodology (Tables 1a and 1b).

These studies differed in terms of setting, operator, direction of inquiry (prospective versus retrospective), and inclusion criteria. The studies also included multiple veneers within the same patients. Veneers are used to correct minor esthetic concerns; therefore, restoration of multiple teeth simultaneously is common. Analyzing results per veneer rather than per patient results in clustering.

Unfortunately, in dental research, clustered outcomes are commonly ignored. Many researchers assess the outcome of individual restorations in patients' mouths and report results at the restorative level, not at the patient level. If the risk of restorative failure were isolated to an individual tooth, then there would be no need to account for clustering. However, if the risk of restorative failure is patient related, then specific systemic conditions or patient habits may result in a cluster of failures or a cluster of successes. In the presence of clustering, analysis of individual restorations may lead to biased results, with the outcomes artificially inflated or reduced. Clearly, the outcome of a single veneer in a mouth cannot be considered independent of the outcome of another veneer in that same mouth.

This study aimed to investigate the clinical outcome and estimated cumulative survival of feldspathic porcelain veneers in situ for up to 21 years while also accounting for clustered outcomes.

Materials and Methods

Inclusion/Exclusion Criteria

Porcelain veneers (n = 499) placed in patients (n = 155) by a single prosthodontist in a private specialty practice between 1990 and 2010 were sequentially included in this prospective cohort study.

Nonvital teeth, molar teeth, and teeth subjectively assessed to have an unfavorable periodontal prognosis were excluded. Teeth with large retained restorations, tooth loss of more than one-third the width of the incisal edge, or less than 80% of enamel remaining following preparation were not veneered. Patients who showed extensive loss of tooth structure through parafunction were excluded.

Clinical Procedure

Details regarding the clinical procedure were previously published[10] and are outlined in Fig 1. Small defective interproximal restorations were replaced, and lesions were restored with composite resin. Retraction cord was placed on the labial aspects of the teeth. The teeth were prepared with a labial reduction of 0.5 to 0.7 mm, chamfer margins, and an incisal reduction of 1 to 2 mm with a palatal overlap. The palatal overlap was kept clear of the tooth contact in maximum intercuspation; if this was not possible, the palatal overlap continued for at least 1 mm past the occlusal contact. Interproximal contacts were reduced on the facial aspects only. Minimum veneer thickness was determined on an individual basis.

Impressions were taken with addition polyvinyl siloxane (President, Coltene). Feldspathic porcelain (Durecem, Degudent; Mirage, Chameleon Dental Products; Fortress, Chameleon Dental Products; Vita 900, Vita Zahnfabrik) was applied (usually in three layers) to a refractory die (GG refractory die material, GC America). The restoration was etched (5% hydrofluoric acid, 10% sulfuric acid; Vita Ceramics Etch, Vita Zahnfabrik), steam cleaned, and delivered. All laboratory procedures were completed by a single commercial laboratory

The veneers were tried-in with either water or try-in paste. Following assessment, they were washed with water and ethyl alcohol and then silanated. Retraction cords and rubber dam were not used. The tooth substrate was cleaned with pumice and water and etched (37% phosphoric acid). Each veneer was cemented individually with a dual-cure unfilled resin cement (Vision 2, Mirage Dental Systems, Chameleon Dental Products). The cementation and finishing processes were completed for each veneer before the next was cemented. Occlusion was designed with anterior protrusive and canine laterotrusive guidance when possible.

Clinical Follow-up

Following veneer placement, patients were assigned an individualized maintenance schedule. The schedule was based on the patient's dental and medical

risk factors when the veneers were first issued and then modified as those risk factors changed over time. In general, the regimen involved six monthly appointments for 2 years and then yearly reviews until year 5, at which point the frequency of recalls was increased or decreased depending on the patient's requirements. The reviews involved examination, professional prophylaxis, smoothing of minor porcelain chipping, and management of any complications. Patients were also encouraged to return for review outside of these scheduled appointments if required. Regardless of the recall schedule, all patients in the cohort were actively contacted and reviewed at regular intervals over the study period. The most recent review occurred in 2010.

Clustering

Patients received a mean of 5.8 ± 4.3 veneers each. Therefore, the outcomes were clustered. There is no reason to believe that the outcome of a single veneer is independent of the outcome of another veneer in the same mouth. Therefore, patients who received more than one veneer may have a cluster of veneers that failed, survived, or became lost to recall. To explore the effects of clustering, the results of this cohort study were assessed via two methods and then compared. First, the outcome was analyzed for all 499 veneers in all 155 patients without accounting for clustering; second, the outcome was analyzed for 1 randomly chosen veneer from each patient.

A random number table was generated and used to identify veneers for analysis.[19] A single veneer in each patient was included. Patients with multiple veneers were listed alphabetically, and their veneers were listed in order by tooth number (FDI system). The random table was read in one direction from the top left corner toward the right, with the first number being "4." Therefore, the fourth veneer in the first patient was included. If the patient had received fewer than four veneers, the table would continue to be read until a number equal to or less than the number of veneers in situ was selected, at which point the corresponding veneer was included.

Outcome Measure

Walton's six-field classification[20] was used to define veneer survival (Table 2). For Kaplan-Meier analysis, surviving prostheses were those defined as successes, survivors, or repairs; censored prostheses were those defined as deaths or unknowns; and failed prostheses were those defined as failures. Therefore, a surviving veneer is one that remained in situ, bonded to a biologically stable tooth, with an intact restorative margin and no requests for replacement made by the patient for any reason.

For surviving veneers, time in situ was defined as the time between veneer placement and the last follow-up appointment. For failed veneers, time in situ was defined as the time between veneer placement and the date the failure occurred.

Table 1a Studies of Porcelain Veneers Reporting

Study	Design/sample
Burke and Lucarotti (2009)[7]	Retrospective cohort 1,177 patients 2,562 veneers (mean: 2.2 per patient*)
Layton and Walton (2007)[10]	Prospective cohort 100 patients 304 veneers (mean: 3.0 ± 2.8 per patient)
Dumfahrt (1999)[8] Dumfahrt and Schaffer (2000)[9]	Retrospective cohort 72 patients 205 veneers (mean : 2.9 per patient*)
Peumans et al (1998)[12] Peumans et al (2004)[11]	Prospective cohort 54 patients 87 veneers (mean: 1.6 per patient*)
Shaini et al (1997)[13]	Retrospective cohort 102 patients 372 veneers (mean: 3.6 per patient)
Smales and Etemadi (2004)[14]	Retrospective cohort 50 patients 110 veneers (mean: 2.2 per patient*)

NR = not reported.
*Mean not reported by authors and was estimated post hoc. This simple average likely underestimates the true number.
†Standard error or 95% confidence interval not available.

Table 1b Studies of Porcelain Veneers Reporting

Study	Design/sample
Aristidis and Dimitra (2002)[15]	Prospective cohort 61 patients 186 veneers (mean: 3.1 per patient*)
Friedman (1998)[16]	Retrospective cohort Unknown no. of patients 3,255 veneers

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

Kaplan-Meier Estimated Cumulative Survival

Characteristics	Estimated cumulative survival
Setting: general dentists in the general dental services of England and Wales Inclusion: random selection by birth date of adults (age: > 18 y) who received at least 1 direct restoration and 1 veneer Material: not stated, likely to include at least some feldspathic porcelain veneers	5 y: NR 10 y: 53%†
Setting: 1 operator, private specialist practice, Australia Exclusion: less than 80% enamel, loss of more than 1/3 incisal edge width, subjective assessment of high parafunctional risk Material: feldspathic porcelain (Mirage)	5 y: 96% ± 1% 10 y: 93% ± 2% 13 y: 91% ± 3%
Setting: 2 operators, university, Austria Exclusion: less than 50% enamel, compromised substrate Material: feldspathic porcelain (Optec HSP)	5 y: 95%† 10 y: 91%†
Setting: 1 operator, location not reported (authors were from Belgium) Exclusion: poor oral hygiene, unfavorable occlusion, less than 50% enamel Material: feldspathic porcelain (GC Cosmotech)	5 y: 92% ± 1% 10 y: 64% ± 6.5%
Setting: students and staff, dental hospital, England Exclusion: poor oral hygiene, periodontal problems, severe tooth discoloration, extensive tooth structure loss, insufficient dental hospital records Extra information: 90% of veneers were placed on unprepared teeth Material: feldspathic porcelain (Vitadur N)	5 y: 58% ± 5.5% 6.5 y: 47% ± 7%
Setting: 2 operators, private specialist practice, Australia Exclusion: severe tooth discoloration, inadequate sound enamel, evidence of marked parafunction Extra information: 64 veneers prepared with an uncovered incisal edge and 46 with a covered incisal edge Material: feldspathic porcelain (Mirage)	5 y: 96% ± 5% (covered) 5 y: 86% ± 5% (uncovered) 7 y: 96% ± 5% (covered) 7 y: 86% ± 5% (uncovered) 10 y: NR

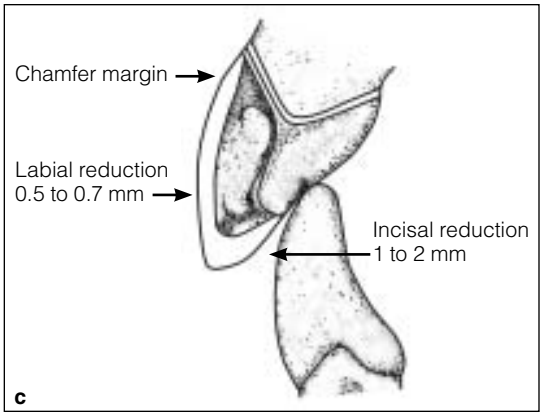
Straight Percentage Outcomes

Characteristics	Results
Setting: 1 operator, university, Greece Exclusion: signs of excessive occlusal forces Material: feldspathic porcelain with 15% aluminum oxide (Ceramco)	5 y: 98% judged to be clinically acceptable
Setting: 1 operator, private practice, United States Inclusion: patients who returned for review; loss to follow-up not reported Material: not stated, likely to include at least some feldspathic porcelain veneers	93% judged to be clinically acceptable

Statistical Analysis

Demographics were reported as means and standard deviations. The veneers were grouped into 5-year intervals (1 to 5, 5 to 10, 10 to 15, 15 to 20, and > 20 years) based on treatment date. For example, a veneer that was in situ for 5 years exactly would be in the 1- to 5-year group, while a veneer in situ for 5 years and 1 month would be in 5- to 10-year group. All veneers were in situ for at least 1 year.

Cumulative estimated survival was calculated using the Kaplan-Meier method, and the standard error was calculated with the Greenwood formula. The number at risk within each interval was considered to be the number entering the interval minus half the number censored during the given interval. The 95%



Figs 1a to 1c **(a)** Veneer preparations in the maxilla from canine to canine. **(b)** Veneers in situ. **(c)** Schematic representation of the veneer preparation. (Modified from Shillingburg et al[18] with permission.)

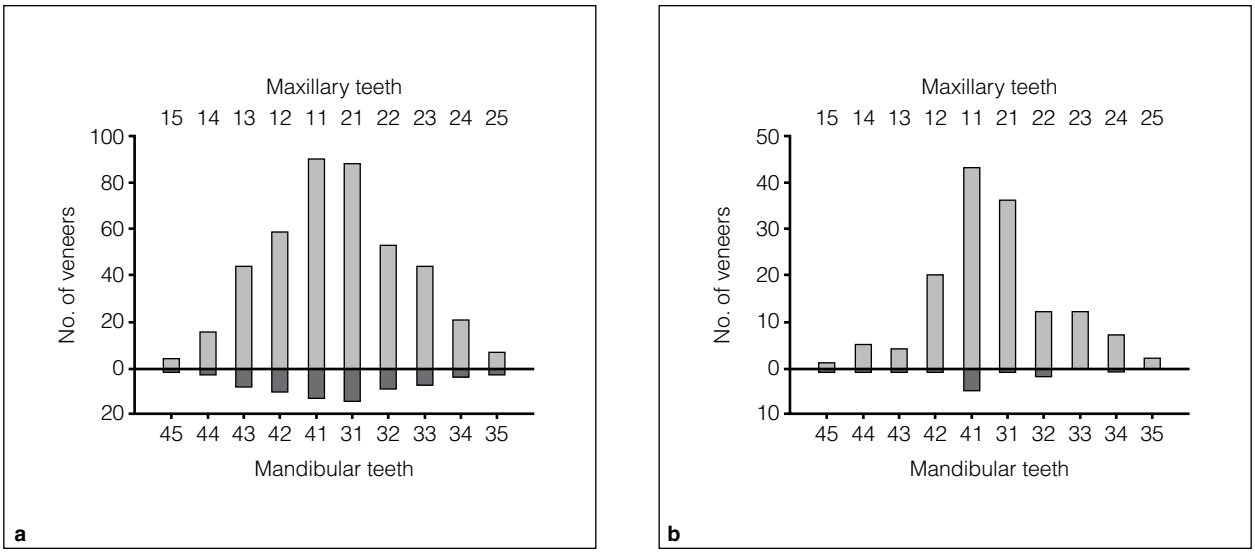
Table 2 Six-Field Classification System[20]

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.

Table 3 No. of Veneers Treated in Each 5-Year Period

	Veneers		Total	
Time in situ	n	%	n	%
1–5 y (2010–2006)	145	29.1	499	100.0
5–10 y (2005–2001)	115	23.0	354	70.9
10–15 y (2000–1996)	157	31.5	239	47.9
15–20 y (1995–1991)	77	15.4	82	16.4
21 y (1990)	5	1.0	5	1.0

confidence interval was 1.96 times the standard error. Survival was expressed as a percentage ± standard error or as a percentage bounded by a 95% confidence interval. Results were expressed on Kaplan-Meier plots and delineated in life tables. Differences in survival between groups were analyzed with the log-rank test. Statistical significance was set at $P < .05$. Data were analyzed using PASW Statistics version 18.0 (IBM).



Figs 2a and 2b Distribution of teeth (FDI tooth-numbering system) treated with veneers in the **(a)** entire sample (n = 499) and **(b)** random sample (n = 155).

Results

Demographics

In relation to treatment date, 145 veneers were in situ for 1 to 5 years, 115 veneers for 5 to 10 years, 157 veneers for 10 to 15 years, 77 veneers for 15 to 20 years, and 5 veneers for more than 20 years (Table 3). Eighty-two percent of patients (n = 127) with 85% of the total veneers (n = 424) were female. Eighteen percent of patients (n = 28) with 15% of veneers (n = 75) were male. The age of patients at treatment ranged from 15 to 73 years (mean: 41 ± 14.1 years).

Patients received between 1 and 20 veneers each (mean: 5.8 ± 4.3 veneers per patient), with a distribution as follows: 1 veneer (n = 50, 32%), 2 to 6 veneers (n = 87, 56%), 7 to 10 veneers (n = 15, 10%), 10 to 15 veneers (n = 2, 1%), and > 15 veneers (n = 1, 0.5%). Eighty-six percent (n = 426) of veneers were placed on maxillary teeth (incisors: 58%, canines: 18%, premolars: 10%), while 14% (n = 73) were placed on mandibular teeth (incisors: 9%, canines: 3%, premolars: 2%) (Fig 2a). All veneers were placed on vital teeth. No veneers were placed on molar teeth.

For the randomly selected sample of veneers, 92% of veneers (n = 142) were placed on maxillary teeth (incisors: 72%; canines: 10%; premolars: 10%), while 8% (n = 13) were placed on mandibular teeth (incisors: 6%; canines: 0.5%; premolars: 2%) (Fig 2b).

Table 4 Six-Field Outcome for the Entire Sample (n = 499) and Random Sample (n = 155) of Porcelain Veneers

	Entire sample		Random sample	
	n	%	n	%
Death	5	1.0	1	0.6
Failed	17	3.4	4	2.6
Repaired	3	0.6	2	1.3
Success	365	73.1	111	71.6
Survival	39	7.8	10	6.5
Unknown	70	14.0	27	17.4

Six-Field Outcome

Table 4 shows the six-field outcome for both the entire sample and the randomly selected sample. Eleven patients with 56 veneers experienced more than one outcome.

Seventeen veneers failed in 8 patients, with half of the patients experiencing multiple failures (13 failures in 4 patients) and half experiencing a single failure among other successful veneers (4 veneers in 4 patients). The failures occurred between years 1 and 13.

Seventy-five veneers in 30 patients were classified as unknown and censored for Kaplan-Meier analysis.

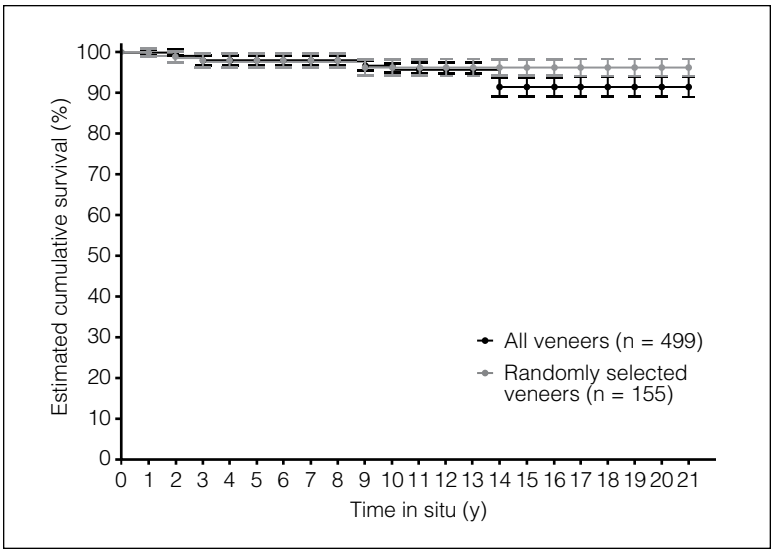


Fig 3 Kaplan-Meier survival curves up to 21 years.

One patient died, resulting in 5 veneers being classified as unknown after 13 years in situ. Sixty-eight veneers in 27 patients were classified as unknown because the patients failed to return for follow-up visits, while 2 veneers in 2 patients were classified as unknown because the successful veneers were replaced with another prosthesis (eg, a tooth-supported fixed dental prosthesis). Fifty-three of these unknown veneers (76%) occurred in 12 patients (41%).

Four hundred seven veneers in 130 patients were survivors. Three surviving veneers in 3 patients required repair, with all repairs occurring after 15 years of service. Three hundred sixty-five surviving veneers were further classified as successful based on the six-field criteria. Sixty-eight percent of patients experienced multiple surviving veneers (365 veneers in 88 patients).

Of the 17 failed veneers, 11 were replaced with another veneer (and remain successful), 5 were replaced with a metal-ceramic crown, and 1 required complete removal of the tooth abutment and was replaced with a tooth-supported fixed dental prosthesis. Reasons for failure included veneer shade (n = 2), gingival recession adversely affecting esthetics (n = 8), porcelain fracture (n = 3), trauma (n = 1), tooth fracture (n = 1), loss of retention on more than one occasion (n = 1), and extensive caries (n = 1).

Survival and Clustering

For the entire sample of veneers, the estimated cumulative survival rate was 98% ± 1% at 5 years, 96% ± 1% at 10 years, 91% ± 2% at 15 years, and 91% ± 2% at 20 years. For the randomly selected sample, the estimated cumulative survival rate was 98% ± 1% at 5 years, 96% ± 2% at 10 years, 96% ± 2% at 15 years, and 96% ± 2% at 20 years. The estimated cumulative survival rates of the entire sample and random subsample were not significantly different (chi-square = 0.21, P = .65) (Fig 3).

Discussion

Although feldspathic porcelain veneers have been commonly used for over 30 years, reports of their survival rates appear contradictory. In this study, all veneers completed over a 21-year period were included sequentially, and the results highlight the excellent clinical outcomes that can be obtained with feldspathic porcelain veneers.

In comparison with the Kaplan-Meier survival rates reported by studies identified in the previously mentioned literature review,[17] these outcomes are complementary with three[9,10,14] of the six studies. Each of these studies reported strict assessment of remaining prepared enamel and reported high survival rates. The 5-year survival rates were 96% ± 5%,[14] 95% (standard error not available),[9] and 96% ± 1%.[10] A 7-year survival rate of 96% ± 5% was reported by one study.[14] Ten-year survival rates of 93% ± 2%[10] and 91% (standard error not available)[9] were also reported. One study based on a similar patient cohort reported a 13-year survival rate of 91% ± 3%.[10] Further details regarding the methodology of these studies are available in Table 1.

Regarding earlier research reported by Layton and Walton,[10] that study included 48 veneers in 19 patients

placed between 2001 and 2003, which overlapped with the 260 veneers in 88 patients placed between 2001 and 2010 in the present study. Despite this overlap, the similarities in the patient cohort are small and do not preclude thoughtful comparison of the results and methodologies.

The other three studies[7,11–13] all reported comparatively reduced survival rates. Differences in survival can be attributed to differences in clinical and/or statistical methodology. Clinically, differences could relate to environmental and patient-related factors; statistically, differences could relate to loss to follow-up and analysis of clustered outcomes.

A prospective study by Peumans et al[11,12] regarding a cohort of 87 veneers in 54 patients reported a high survival rate of 92% ± 1% at 5 years, which dropped to 64% ± 6.5% at 10 years. The authors attributed the 10-year failure rate of 36% to reduced enamel under the preparations. Some of the veneers were placed on teeth with large interproximal restorations or a high proportion of dentinal substrate exposed during preparation. Further, some veneers were not attached with adhesive bonding agents. Therefore, this reduced 10-year survival rate is likely attributable to differences in clinical methodology and the increased prevalence of veneered teeth with reduced enamel bonding substrate.

Burke and Lucarotti[7] reported an estimated cumulative 10-year survival rate of 53%. The authors retrospectively evaluated the outcome of 2,563 veneers in 1,177 patients. The material used for the veneers was not specifically reported, but it is likely that multiple materials were used, including feldspathic porcelain. The tooth preparation and bonding substrate were also not specifically reported. However, it is conceivable that veneers placed within this environment may not have met the preparation criteria advocated by prosthodontic specialists; likewise, it is conceivable that the veneers may have been bonded to compromised tooth substrates.

A retrospective cohort study by Shaini et al[13] of 372 veneers in 102 patients reported 5- and 6.5-year survival rates of 58% ± 5.5% and 47% ± 7%, respectively. The veneers were completed by students and staff at the Birmingham Dental Hospital in England. The authors reported that over 90% of the veneers were placed on unprepared teeth. The bond strength to aprismatic enamel is lower than achievable with prepared enamel, and it is likely that this clinical technique resulted in the higher failure rate. This technique does not adhere to traditional guidelines for veneer preparation; therefore, while the results provide useful clinical data, they are not comparable with the results of the present study.

The comparatively reduced survival rates reported in these studies could also be attributed to statistical methodology. First, this may relate to loss to follow-up. Differences in outcome could occur if a large proportion of successful veneers were censored while a large proportion of failed veneers returned for review. Regarding outcomes reported by Peumans et al,[11,12] high loss to follow-up did not occur, as nearly all veneers (81 of 87, 93%) returned for review at 10 years. In the study by Burke and Lucarotti,[7] the loss to follow-up was not reported. In the study by Shaini et al,[13] 42 of the original 372 veneers (11%) were available for review at 6.5 years. It is unclear how many veneers were unavailable due to attrition or patient death and how many veneers were unavailable because they had been in situ for less than 6.5 years. Therefore, the reduced survival may be partially related to bias in the results. Nevertheless, there is little evidence that the reduced reported survival rate was attributable to this issue.

Second, the present study accounted for clustered outcomes, while the six identified studies did not. Multiple patients in each of these studies received more than one veneer, but the impact of these clustered outcomes on the results cannot be reviewed retrospectively without access to individual patient data. Prior to accounting for clustering, patients in the present study received between 1 and 20 veneers each (mean: 5.8 ± 4.3 veneers per patient). Two-thirds (n = 105, 68%) of patients received more than 1 veneer. Accounting for clustering was considered essential.

When a patient receives more than one veneer, the individual characteristics of that patient may adversely or favorably affect the outcomes of all veneers placed, thus clustering the outcomes. Clustered outcomes can be accounted for statistically, or the clustered units can be separated prior to analysis. For this research, the latter method was employed.

From the entire veneer sample (veneers = 499, patients = 155), a nonclustered data sample of 155 veneers was identified for survival analysis (ie, the random sample). In patients who received more than one unit, a random number table was used to randomly identify a single veneer for analysis. In patients who received only one unit, each veneer was included for analysis. Survival of the randomly selected sample was analyzed and compared with the survival of the entire sample.

In the entire sample, almost three-quarters of veneer failures (13 veneers) were clustered in half of the patients with failures (4 patients). Reasons for failure varied between patients; however, within an individual patient, the failed veneers were attributable to a single reason. Qualitatively, failures were clustered.

In total, 75 veneers in 30 patients were classified as unknown. One hundred percent of unknowns due to death were clustered in 1 patient, and nearly 75% of losses to follow-up were clustered in half of the patients in this category (53 unknowns occurring in 12 patients). Qualitatively, unknown outcomes were clustered.

Eighty-four percent of patients (130 patients) experienced at least 1 surviving veneer (407 veneers). Approximately 90% of these occurred in 70% of patients (365 veneers in 88 patients). Qualitatively, surviving veneers were clustered.

The Kaplan-Meier method analyzes failures, unknowns, and survivors to estimate the cumulative survival. Clustering of results will affect the calculated outcome. Accounting for clustering of outcomes at the study level improves the validity of the results. For the randomly selected sample, the estimated cumulative survival rate was 96% ± 2% at 10 years and 96% ± 2% at 20 years. For the entire sample, the estimated cumulative survival rate was 96% ± 1% at 10-years and 91% ± 2% at 20 years. The differences between groups were not statistically significant. Quantitatively, the distribution of failures and survivals within patients did not significantly affect the estimated cumulative survival. Nonetheless, analysis of outcomes without accounting for clustering could prove misleading.

The method chosen to account for clustering in this study required no additional software and was simple to apply, accurate, and time efficient. Although accounting for clustering decreases the number of prostheses in the analysis and thus decreases the power to detect differences between study variables, failure to account for clustering may result in erroneous statistical findings and incorrect identification of prognostic survival factors.

Conclusions

When bonded to prepared enamel substrate, feldspathic porcelain veneers have an excellent long-term survival rate and low failure rate. The 21-year estimated cumulative survival rate was 96% ± 2%. Multiple dental prostheses in the same mouth are exposed to the same local and systemic factors, resulting in clustered outcomes. Efforts should be made by future researchers to account for clustering in their analyses.

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