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CLINICAL RESEARCH

Retrospective evaluation of the clinical performance and longevity of porcelain laminate veneers 7 to 14 years after cementation

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ABSTRACT

Statement of problem. Studies on the long-term clinical assessment and longevity of porcelain laminate veneers (PLVs) are lacking.

Purpose. The purpose of this clinical study was to assess the clinical performance and longevity of PLVs after 7 to 14 years of clinical service.

Material and methods. Patients with PLVs placed 7 to 14 years earlier were recalled for clinical evaluation. At the recall visit, clinical parameters such as margin integrity, margin discoloration, porcelain surface, anatomic form, and secondary caries were evaluated according to the Ryge criteria. Standardized photographs of veneers were made for each participant. Data were tabulated for all descriptive criteria and analyzed statistically. The Cohen Kappa assessment was carried out to determine interrater agreement, the Kaplan-Meier survival analysis for survival probability, and the Cox regression for significance between the arches.

Results. One hundred and fourteen veneers (83 maxillary and 31 mandibular) were evaluated in 26 participants, including 19 women restored with 87 veneers and 7 men restored with 27 veneers. Distribution of the veneers included 37 central incisors, 41 laterals, and 36 canines. The Alfa ratings for the veneers were as follows: porcelain surface (85%), anatomic form (87%), and secondary caries (96%). For margin integrity, 37% rated Alfa, 60% Bravo, and 3% Charlie. For margin discoloration, 56% rated Alfa and 44% Bravo. The overall Cohen Kappa interrater agreement was 0.7023 with an agreement rate of 88.3%. Clinical deficiencies included fracture rate of 4.35% (n=5); porcelain chipping 5.26% (n=6); caries 4% (n=4); debonding 2% (n=2); crack/craze lines 5.26% (n=6); loss of vitality 2% (n=2); and replaced veneers 4.38% (n=5). The main reason for failure was porcelain fracture. The survival rate for the veneers was 98%. The Kaplan-Meier success probability was 0.976 at 7 years and 0.882 at 14 years.

Conclusions. Within the limitations of this clinical study, PLVs exhibited an estimated survival probability of 0.976 over 7 years and 0.882 over 14 years, a high survival rate of 98%, and a low failure rate of 4.38%. (J Prosthet Dent 2019;122:31-7)

Complete crowns have provided a predictable and durable option for the correction of unesthetic anterior teeth. However, this procedure involves significant removal of tooth structure and the possibility of adverse effects on the surrounding periodontal and pulpal tissues.[1,2] More conservative restorative techniques rely on bonding and adhesive luting.[3-5] Bonding to enamel is more durable than to dentin,[6] and intact enamel provides the most reliable substrate for etched porcelain laminate veneers (PLVs).[7] PLVs provide a dependable treatment option that is conservative and more durable than composite resin veneers[1,8] and provides excellent esthetics, mimicking the natural translucency and structure of teeth.[1] Some of the clinical challenges of PLVs include porcelain fracture or chipping and luting composite resin shrinkage.[9-11]

The clinical performance and longevity of PLVs has been evaluated.[6,7,12-28] In a 10-year retrospective evaluation study, margin integrity was acceptable in 99% and marginal discoloration was seen in 17% of the evaluated PLVs.[6] In a 6-year follow-up with high-leucite–content veneers, only 1 failure was reported, with

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Clinical Implications

Porcelain laminate veneers offer a reliable and successful procedure as a conservative treatment option for enhancing the esthetics of anterior teeth.

a success rate of 98.8%.[20] Beier et al[23] reported a survival rate of 94.4% at 5 years and 82.93% at 20 years. However, published data are limited on the long-term success and failure analysis of PLVs in controlled clinical environments. The purpose of this clinical study was to assess the clinical performance and longevity of PLVs after 7 to 14 years of clinical service using modified California Dental Association (CDA)/Ryge criteria.[29-31] The hypothesis for this study was that the clinical performance of PLVs will be clinically acceptable after 7 to 14 years using standardized evaluation criteria.

MATERIAL AND METHODS

This study was designed to be retrospective and noninterventional and involved a chart review and clinical evaluation/examination follow-up of patients treated with PLVs. Institutional review board approval (HUM00066344) was obtained before the start of the study. The study included only participants who had had PLVs placed for esthetic reasons at least 7 years earlier at the Graduate Restorative Clinic. To recruit participants, an electronic report was run to compile a list of qualified patients within the specified time frame. A recruitment letter with a brief introduction to the study and a participant incentive offer (no cost examination and prophylaxis) was mailed to 60 qualified individuals. One week later, follow-up phone calls were made to schedule those interested. Contacted individuals who responded to the mailing and agreed to participate were scheduled for a clinic visit. No attempt was made to recruit for a specific sample size or stratification. The treatment chart was reviewed before the participant visit to record demographics, date of placement, cement, failures, and replacements. At the clinical appointment, each participant reviewed and signed a written consent form. After obtaining consent, an updated medical history was procured, and clinical evaluation of the PLVs was conducted. Two evaluators (R.A., D.G.) were calibrated to record clinical performance using the modified California Dental Association/Ryge criteria.[29-31] The criteria for evaluation included marginal adaptation/integrity, marginal discoloration, porcelain surface, anatomic form, and secondary caries (Table 1). The ratings were made separately by the 2 evaluators. Wherever there was disagreement, a consensus was reached by discussion after reviewing the rating criteria.

For marginal adaptation/integrity, an evaluation was made visually with an explorer. Marginal discoloration was assessed by placing cotton rolls in the buccal sulcus, mildly air-drying, and then inspecting visually. The anatomic form and porcelain surface were evaluated visually after air-drying. Secondary caries was assessed after mild air-drying using visual inspection and an explorer (#3 CH; Hu-Friedy Mfg Co). Clinical interpretation of the ratings was based on the Ryge criteria, an ordinal scale that rates restorations as Alfa, Bravo, Charlie, or Delta (Table 1).[29-31] Intraoral and extraoral photographs were made for each participant by a calibrated evaluator (R.A.) using a standard protocol.

Data were tabulated for all descriptive criteria and analyzed using a statistical software program (IBM SPSS Statistics, v21 [IBM Corp] and Stata SE 13 [StataCorp]). The Cohen Kappa interrater agreement was calculated between the 2 assessing raters. A censored Kaplan-Meier methodology (nonparametric statistical technique) was used to assess the survival probability of PLVs with the maxillary and mandibular arches as a categorical factor. Survival time was defined as the time from the successful cementation of the veneer to when the restoration was evaluated as having an irreparable problem. The presence of an irreparable problem represented failure. Criteria for irreparable failure included porcelain fracture and partial debonding that either exposes tooth structure, impairs esthetics, or function. Although multiple veneers were placed by the same operator and all had the same oral environment for function, the threat to validity was more clinically relevant than if all veneers in 1 patient had been considered as a unit. The Cox Regression Analysis was used to test for statistical significance on the Kaplan-Meier curve between the maxillary and mandibular arches.

RESULTS

A total of 26 individuals agreed to participate, and 114 veneers were evaluated, 83 (73%) maxillary and 31 (27%) mandibular. Participants included 19 (73%) women restored with 87 (76%) veneers and 7 (27%) men restored with 27 (24%) veneers. The mean age of the participants was 53 ±14 years at cementation and 62 ±14 years at the time of evaluation. The distribution of the veneers included 37 (32%) maxillary and mandibular central incisors, 41 (36%) maxillary and mandibular laterals, and 36 (32%) maxillary and mandibular canines.

The distribution of the veneers by the year placed and according to the time in clinical service is illustrated in Figure 1. All veneers had been placed by operators who were graduate students in a 3-year restorative dentistry program. The students were trained academically in the preparation and placement of PLVs by the same faculty instructor and supervised clinically by the graduate clinic faculty. All PLVs had been cemented with a standard

Table 1. Modified CDA/Ryge criteria for assessment of clinical quality and performance

Evaluation Criteria	Rating	Restoration
Marginal adaptation/ integrity	A	No evidence of visible crevice, margin not detectable or barely detectable when the explorer is run across the interface.
	B	Restoration margin slightly detectable with explorer (one-way catch). The explorer does not penetrate the interface
	C	Visible evidence of crevice formation into which the explorer will penetrate and contact prepared tissue (two-way catch)
	D	Fracture on the margin exposing the preparation wall, underlying dentin, or cement. Restoration is mobile, fractured, or missing in part or in full.
Marginal discoloration	A	No discoloration on margin
	B	Superficial discoloration; does not penetrate in pulpal direction
	C	Discoloration; penetrating in pulpal direction
Porcelain surface	A	Smooth surface (shiny after air-drying)
	B	Dull surface and/or chipping of porcelain; does not impair esthetics or function and/or expose tooth structure
	C	Chipping of porcelain; impairs esthetics and/or exposes tooth structure; intraporcelain fissures detectable with explorer
Anatomic form	A	The restoration has proper anatomy and contour (facial and incisal).
	B	The restoration is slightly overcontoured (bulky) or undercontoured (flat). Incisal edge length slightly too long/short. Slight deviation from normal tooth contours.
	C	The restoration is decidedly overcontoured (bulky) or undercontoured (flat). Incisal edge length decidedly too long/short. Moderate deviation from normal tooth contours.
Secondary caries	A	No evidence of caries contiguous with the margin of the restoration
	B	Caries evident, contiguous with the margin of the restoration

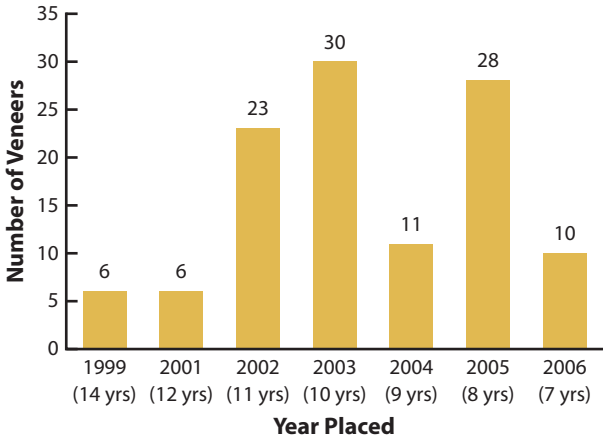

Figure 1. Distribution of veneers by year placed and according to time in clinical service.

technique of etch, silane, and cementation with a resin cement. The majority were in place for 8 to 9 years (34%) and 10 to 11 years (46%). Of the 114 veneers included in this study, 109 (96%) were clinically acceptable at evaluation and 5 (4%) failed during service. Four veneers failed because of porcelain fracture, and 1 was converted to a crown to support a removable partial denture.

The results of the clinical evaluation of the 109 restorations seen at recall are given in Table 2. The major deficiencies were explorer catches at the margins (60%), nonpenetrating margin discoloration (44%), and secondary caries (4%). Specific deficiencies observed during evaluation are presented in Table 3, and examples are shown in Figure 2. Porcelain chipping was the most frequent clinical problem (6.4%), followed by the appearance of craze lines (5.5%) and secondary caries (1.8%). All the veneers evaluated were considered

Table 2. Frequency distribution of clinical ratings of 109 PLVs evaluated (modified CDA/Ryge criteria)

Parameter	Alfa, n (%)	Bravo, n (%)	Charlie, n (%)	Delta, n (%)
Margin integrity	41 (37)	65 (60)	3 (3)	0 (0)
Porcelain surface	93 (85)	15 (14)	1 (1)	0 (0)
Anatomic form	95 (87)	14 (13)	0 (0)	0 (0)
Marginal discoloration	61 (56)	48 (44)	0 (0)	0 (0)
Secondary caries	105 (96)	4 (4)	0 (0)	0 (0)

CDA, California Dental Association; PLVs, porcelain laminate veneers.

Table 3. Overview of clinical deficiencies noted in 109 veneers evaluated

Deficiencies	Frequency, n	Percentage, %
Porcelain chipping	7	6.4
Secondary caries	4	3.7
Veneer debonded and recemented	2	1.8
Crack/craze lines	6	5.5
Endodontic treatment (veneer remained in situ)	2	1.8

clinically acceptable and remained intact after minor repairs. To assess interrater agreement, the Cohen Kappa test showed a value of 0.7023 with an agreement rate of 88.3%. All failures took place in the maxillary arch.

The Kaplan-Meier results for the overall survival of PLVs in the maxillary and mandibular arches are illustrated in Figure 3. The estimated survival probability after 7 years was 0.976 (97.6%) and at 14 years was 0.882 (88.2%). The Cox Regression analysis used to compare failures between the maxillary and mandibular arches revealed P=.199 and therefore suggesting no significant difference.

DISCUSSION

The data collected in this study, based on a convenience sample of individuals willing to participate in a follow-up

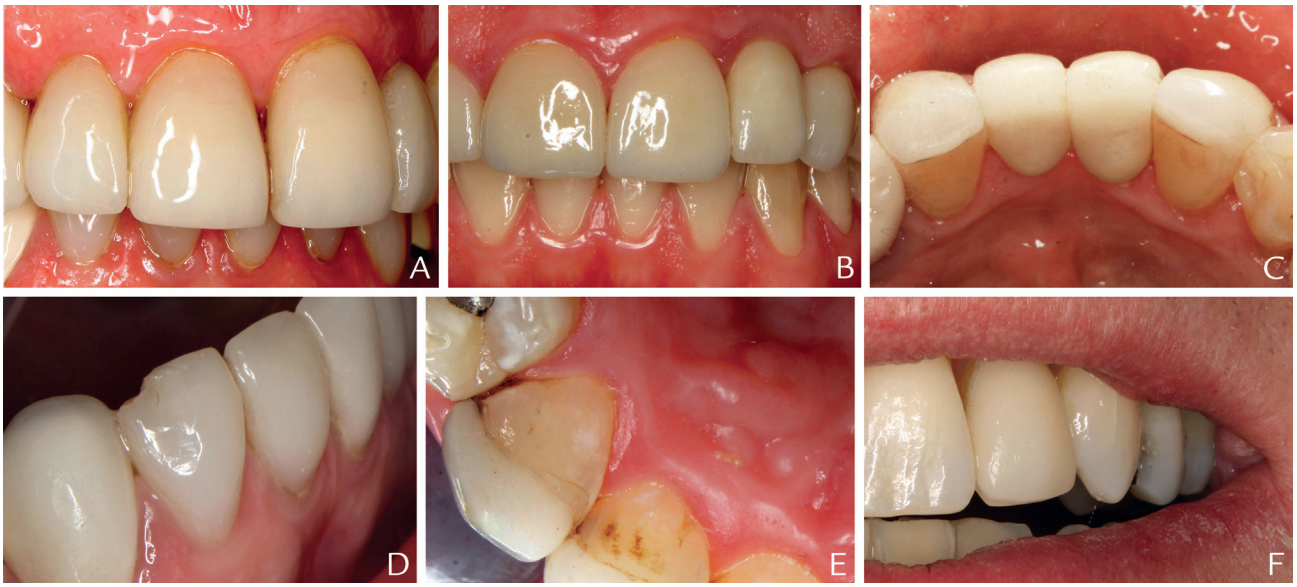

Figure 2. Examples of observed deficiencies in margin integrity of porcelain laminate veneers. A, Detectable margins cervical maxillary central incisors. B, Cement visible at cervical margin maxillary right central incisor. C, Observed marginal discoloration mandibular canines. D, Chipped porcelain. E, Secondary caries at DL margin of veneer. F, Crack/craze line visible on facial of maxillary left canine.

examination, support the hypothesis that the clinical performance of PLVs is clinically acceptable after 7 to 14 years according to standardized evaluation criteria. The majority of the PLVs were placed in the maxillary arch, which is consistent with previous studies.[6,7,13,16] In several investigations, PLVs were placed in the maxillary arch only.[7,13,16] In the present study, the recalled PLVs were more frequently placed in female patients, which has also been reported by previous studies.[6,12,13,19,23] At cementation, the majority of patients were between 40 and 60 years of age, and at evaluation, they were between 60 and 80 years of age. Other studies show similar age ranges from 19 to 65 and 18 to 77 at cementation and evaluation, respectively.[2,16] The most common age group has been 20 to 40 years.[12,13] By recruiting from an existing predetermined population, age could not be controlled, but it was generally representative of clinical practice. The majority of the PLVs in this study were made from a high-leucite–containing ceramic (Empress; Ivoclar Vivadent AG), which has also been used in other studies.[19,20,23] The high-leucite–containing ceramic provides a translucent PLV and seems to offer a safe and durable solution to patients' esthetic demands.[20]

The Ryge criteria have been used extensively to evaluate the clinical performance of PLVs.[2,6,13,18,19,25] The present study found acceptable margins in 96% of the veneers. This is consistent with studies reporting an overall acceptability of the veneer restorations in excess of 95%.[6,12,16,18] A prevalence of Bravo-rated PLVs (60%) was found over Alfa (37%). In 1 study, 36% of restorations were rated Bravo after 10 years using similar criteria.[6] Another study reported 14% restorations as Alfa

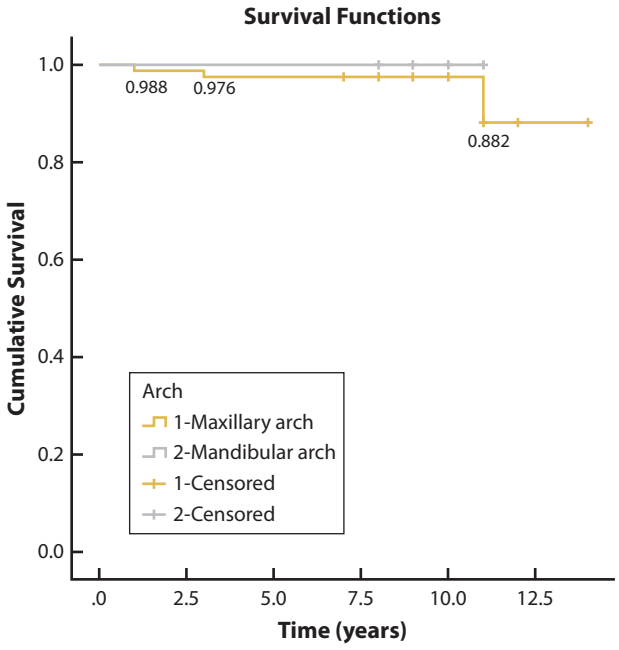

Figure 3. Kaplan-Meier success probability according to arch, stating time interval in years. Cum survival, cumulative survival.

after 5 years and only 4% at the 10-year recall.[7,16] Some investigations ranging from an evaluation time of 5 to 20 years have reported a majority of PLVs to be rated as Alfa and few as Bravo.[12,13,19,23] However, only Beier et al[23] and Fradeani et al[19] used the Ryge criteria.

The marginal quality of the restorations decreased with age, which is consistent with a previous study.[7] One reason for the high percentage of Bravo restorations seen

in this study can be attributed to slight marginal defects found in 24% (n=26) of the PLVs. The most common site for these was the faciocervical region (14%, n=15), followed by palatoincisal region (10.09%, n=11), which agrees with a similar study by Peumans et al.[7] They reported no difference in the number of small defects between cervical and incisal locations at the end of the 10 years recall.[7] However, D'Arcangelo et al[13] reported that marginal defects occurred more frequently in palatal than in cervical areas. The palatal marginal defects may be attributed to attrition, which can also lead to cracks and fractures in the restoration.[16,32] Careful preparation, packing displacement cord, and removal of excess cement may limit small marginal defects at the porcelain-luting composite resin–tooth interface.[13,16,20] Bonding to dentin may also lead to poorer gingival margin integrity than enamel bonding.[6]

For margin discoloration, 44% of the restorations rated Bravo in this study. This is similar to values reported by other investigators.[7,16] Short- to medium-term investigations have reported a high percentage of veneers exhibiting no discoloration.[13,18,20] Long-term follow-up of these investigations would be of value. Peumans et al[7] also noted that marginal discoloration increased with the increasing age of the restorations. One reason for this staining might be related to the increase in minor marginal defects observed over time in the present study. Fradeani et al[19] reported that discoloration at the margins was often associated with a decrease in marginal integrity. Thermal contractions of composite resins can produce stresses at the margins, leading to deformation and cracks.[7] The use of dual-polymerizing luting composite resin has been attributed to discolorations in the marginal areas.[6]

In this work, 99% of the PLVs were rated acceptable (Alfa and Bravo) for a porcelain surface, which is consistent with the study by Fradeani et al.[19] Several investigations have rated 100% of the PLVs as Alfa for a porcelain surface.[12,16,17] However, these studies were of shorter duration and not all used the same criteria for evaluation. For anatomic form, 87% PLVs were rated Alfa and 13% as Bravo in the present study because of slight deviation from normal tooth contours. Studies have reported the majority of the PLVs to be rated as Alfa in this category.[13,18,20]

For the category of secondary caries, 96% of the veneers were free of caries at the time of evaluation. Two PLVs with caries were found in the same participant, a mouth breather with caries in other areas of the mouth. The carious lesion was repaired with composite resin, and the veneers remained intact. Careful patient selection is advised; PLVs should not be placed in a caries-active patient.[7] The caries was located on the distolingual margin of the veneers (3 maxillary canines; 1 maxillary lateral incisor), a location which can be difficult to access during veneer seating and the crucial cementation procedure. Marginal deficiencies can cause future caries.[24] Margins in composite resin can increase the probability of secondary caries; therefore, preparation margins bound by enamel are recommended over either dentin or composite resin.[7,13,33] The low incidence of secondary caries found in this study is supported by other investigations.[6,7,16,23] Some short- and medium-term investigations found no secondary caries for the observed time periods.[2,12,17,18,20,25]

Table 4. Description of failures in teeth crowned after veneering

Tooth	Veneered (y)	Crowned (y)	Time of Clinical Service (y)	Reason for Crowning
Maxillary lateral incisor	2003	2004	1	Fractured
Maxillary lateral incisor	2001	2012	11	Fractured
Maxillary lateral incisor	2001	2012	11	Fractured
Maxillary canine	2001	2012	11	Fractured
Maxillary canine	2003	2006	3	Converted to abutment for RPD

RPD, removable partial denture.

The failure rate in this study, according to defined criteria, was low at 4.35% (n=5) (Table 4). The main reason for failure was fracture, which is supported by previous studies.[7,19,23,26] A fracture rate of 5.6% after 6 to 12 years has been reported by Fradeani et al.[19] Peumans et al[7,16] reported a fracture rate of 4% at the 5-year recall, which increased to 34% at the 10-year recall (Table 5). Studies have also reported porcelain fracture of 1 to 3 restorations after 5 to 12 years of observation time.[6,12,20] Functional or parafunctional loading may be a cause of fracture,[6] as 3 of the veneers that fractured after 11 years were in the same patient (Table 4). One study on high-leucite–containing and feldspathic porcelain reported that all 5 PLVs that fractured were made with Empress.[19] However, they observed that the PLVs were bonded to less than 50% of enamel substrate, especially at the finish lines.[19] High fracture rates have also been reported by other investigators using Cerinate porcelain,[22] feldspathic ceramics, leucite heat-pressed ceramics, and lithium disilicate heat-pressed ceramics.[23] One study reported that the risk of loss due to fracture for PLVs was comparable to that of metal-ceramic and complete ceramic crowns placed in the anterior region.[27]

In the present study, a porcelain chipping rate of 6.4% was observed, which is similar to that reported by D'Arcangelo et al (Table 5).[13] Chipping may be caused by excessive loading.[6,7,20] Porcelain chipping rates lower than those found in the present study have been reported, ranging from 0% to 2% at evaluation times ranging from 4 to 10 years.[20,22,28] At the evaluation time, the debonding rate was 2% (n=2), making the survival rate 98%, which is consistent with other investigations

Table 5. Comparison with previous studies

Studies	Fracture Rate (%)	Porcelain Chipping (%)	Crack/Craze Lines (%)	Debond Rate (%)	Crowned/ Replaced (%)	Endodont Treatment (%)	Kaplan-Meier Survival Probability (%)		Survival Rate (%)	Failure Rate (%)
Present study	4.38	6.4	5.5	1.8	4.38	1.8	97.6 (7 y)	88.2 (14 y)	98	4.38
D'Arcangelo et al (7 y)[13]	–	6.7	5.9	0	–	1.7	84.3 (7 y)	–	–	–
Dumfahrt and Schaffer (10 y)[6,14]	n=5	–	n=2	0	–	0	97 (5 y)	91 (10 y)	–	4
Peumans et al (5 y)[16]	4	n=1	n=3	0	1	2.3	–	–	100	7
Peumans et al (10 y)[7]	34	2	21	0	4	4	–	–	100	32
Fradeani et al (6 to 12 y)[19]	5.6	–	–	n=3	–	–	94.4 (12 y)	–	–	5.6
Beier et al (20 y)[23]	44.83	10, n=3	27.59, n=8	10, n=3	–	–	93.5 (10 y)	85.74 (15 y)	–	–
Morimoto et al (systematic review/meta-analysis)[22]	4	–	–	2	–	2	94 (glass-ceramic)		–	–

reporting high survival rates.[7,12,13,18] The veneers debonded intact, were cleaned and recemented, and were in situ at evaluation time. Several short-term investigations have reported no debonding (Table 5).[6,12,13,16] Friedman looked at potential reasons for failure of this treatment modality and reported a debond rate of 11%.[26] The low debond rate of the present study can be attributed to the success of contemporary adhesive procedures, also discussed by D'Arcangelo et al[13] who suggested that the debond rate can be kept low with the consistent use of isolation during luting.[13] This study observed crack or craze lines in 6 veneers (5.5%). Similar percentages have been reported in other investigations.[6,13,23] The phenomenon of crack formation is described in detail by Magne et al.[9] To prevent the occurrence of crack lines, uniform tooth reduction, homogenous thickness of ceramic, and minimal thickness of luting are important.[9,11] Two veneered teeth (2%) in the same patient diagnosed with pulpal necrosis required endodontic treatment after 6 years of clinical service. This percentage is consistent with the findings of other investigations.[7,13,16,23]

For the present study, the Kaplan-Meier survival analysis gave a survival rate after 7 years of 97.6%, and after 14 years, it was 88.2%. Similar results have been reported by other studies ranging from 97% at 5 years to 91% at 10 years[6] and 93.5% at 10 years to 85.74% at 15 years.[23] The lower survival rate at 14 years in this study may be attributed to the smaller sample size at that time period. This has also been reported by other investigators.[28] In comparing maxillary and mandibular arch failures, the Cox regression analysis showed no statistical significance. This might be because the sample size was not large enough to have power or because of the small failure rate. This study was retrospective in nature, and yearly recalls were not available. Because most of the veneers in this study were made from 1 high-leucite–containing ceramic, the conclusions drawn may not be applicable to more recently introduced materials. Projected longevity is difficult to estimate because so many new materials are introduced during a long-term study.

The participants for this study were recruited from a population that had had similar treatment in the same facility and from student operators with similar experience. Figure 1 shows the placement dates form a bell curve with the peak between 2002 and 2005 (4 years), which makes the sample representative. The lower number having PLVs between 12 and 14 years is related to the fact that the procedure was in its early stages of development and not as acceptable as in more recent years. This does not invalidate the data because the failures were evenly distributed across the years and not concentrated in that earlier segment.

As the data were analyzed, it became evident that certain aspects of veneer degradation or early clinical failure are patient specific. Margin chipping and porcelain fracture occurred in multiple teeth in patients with occlusal parafunctional habits that added to the stress on the porcelain. Caries occurred in a single participant with active caries, and the only instance of debonding could have been related to the operator or material. Anterior veneers are almost always used in multiple units to correct broad esthetic situations. To analyze data by patient rather than by tooth would be difficult because a failure in 1 criterion on 1 veneer would have to be attributed to all veneers in the same patient. It would also require a much larger sample size to produce statistically significant results. Therefore, the assumption was made in this study to analyze on a per tooth basis with each veneer as an independent variable. In designing the study, it appeared to be the most practical approach to gain data on a technique that is usually performed by quadrant.

This was a retrospective study, with the veneers placed years before the day the study was initiated. The patient records were used for recruitment, collection of demographic data, and documentation of the original veneer placement. However, a principal part of the study involved a clinical visit for collecting data of the status of the veneers. Limitations to the retrospective design were that no valid data were available on the preparation design, margin integrity or fit of the veneer at cementation, operator consistency, patient occlusion, hygiene habits, or diet. Despite these limitations, the data

represent accurately the primary postoperative outcome of a treatment that is often followed only by the operator with unintentional bias.

CONCLUSIONS

Based on the findings of this retrospective clinical study of PLVs, the following conclusions were drawn:

1. The restoration durability after 7 to 14 years was satisfactory, with an overall acceptability for all parameters in clinical performance in the high 90%.
2. The earliest clinical signs of veneer deterioration were in margin integrity and margin discoloration.
3. There was a high survival probability for the veneers at both 7 (97.6%) and 14 years (88.2%).
4. The failure rate of these veneers was less than 5% over at least 7 and up to 14 years, with porcelain fracture being the main cause.
5. Porcelain laminate veneer restorations offer a reliable and effective conservative treatment option for enhancing the esthetics of anterior teeth.

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