Influence of Enamel Preservation on Failure Rates of Porcelain Laminate Veneers

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The purpose of this study was to evaluate the failure rates of porcelain laminate veneers (PLVs) and the influence of clinical parameters on these rates in a retrospective survey of up to 12 years. Five hundred eighty laminate veneers were bonded in 66 patients. The following parameters were analyzed: type of preparation (depth and margin), crown lengthening, presence of restoration, diastema, crowding, discoloration, abrasion, and attrition. Survival was analyzed using the Kaplan-Meier method. Cox regression modeling was used to determine which factors would predict PLV failure. Forty-two veneers (7.2%) failed in 23 patients, and an overall cumulative survival rate of 86% was observed. A statistically significant association was noted between failure and the limits of the prepared tooth surface (margin and depth). The most frequent failure type was fracture (n = 20). The results revealed no significant influence of crown lengthening apically, presence of restoration, diastema, discoloration, abrasion, or attrition on failure rates. Multivariable analysis (Cox regression model) also showed that PLVs bonded to dentin and teeth with preparation margins in dentin were approximately 10 times more likely to fail than PLVs bonded to enamel. Moreover, coronal crown lengthening increased the risk of PLV failure by 2.3 times. A survival rate of 99% was observed for veneers with preparations confined to enamel and 94% for veneers with enamel only at the margins. Laminate veneers have high survival rates when bonded to enamel and provide a safe and predictable treatment option that preserves tooth structure.
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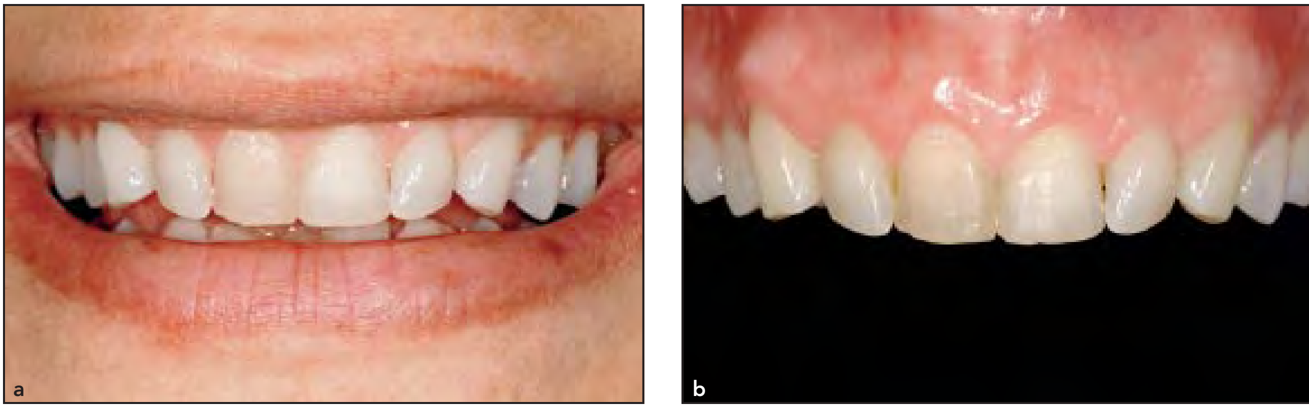
A previous report presented the advantages of the aesthetic pre-evaluative temporary (APT) technique,[1,2] which provides minimally invasive tooth preparations. Several authors have stressed the importance of preparation,[3,4] material selection,[3] and cementation[5] in the success of treatment with porcelain laminate veneers (PLVs).

In vitro studies have reported that tooth preparation for PLVs requires significantly less tooth reduction than any other indirect restorative treatment modality.[6] This is important because the literature has shown that porcelain bonded to enamel with resin cement has a much higher fracture strength than when bonded to dentin.[7,8] Moreover, fracture strength appears to be negatively affected by thermocycling.[9]

Longitudinal studies have shown high survival rates after 10 to 12 years[10,11] and low failure rates when the veneers were bonded to enamel.[12,13] Considering this, predictable and accurate techniques for veneer preparation have been recommended.[1,14] Tooth preparation using intraoral mock-ups[14–17] allows the clinician to prevent



Figs 1a and 1b *Preoperative clinical situation. The patient complained about the color and small size of the maxillary teeth.*

potential inaccuracies and unnecessary tooth reduction.

Several publications have indicated that PLVs represent an effective and reliable option for conservative treatment of anterior teeth.[9,18–21] Occlusion, preparation design, the adhesive system used to bond the veneers to the tooth, and presence of composite restorations are covariables that have contributed to clinical outcomes in the long term.[19,22] Marginal defects, fracture, and debonding were the most common reasons for failure.[10–12,19,21]

Other clinical factors such as dental discoloration and crowding may require modification of the preparation technique, leading to greater enamel reduction. Also, teeth with exposed root surfaces or signs of abrasion may have preparation margins only in dentin, which may reduce the bonding strength of the veneer to the tooth. Few clinical studies[10,11] have correlated these parameters directly with the survival rate of veneers.

The aims of this study were to evaluate the failure rates of PLVs and the influence of clinical parameters on these rates in a retrospective survey of up to 12 years.

Method and materials

Sixty-six patients between the ages of 23 to 73 years who were treated in a private dental office by one experienced dentist and received 580 PLVs between May 1997 and May 2009 were included in this study. The clinical aspects of smile design, additive mock-up, and tooth preparation through the APT technique were described in a previous report (Figs 1 to 3).[2] All veneers were fabricated according to the manufacturers' instructions. Five hundred thirty-seven laminate veneers were composed of heat-pressed ceramic IPS I, IPS II, or IPS Esthetic (Ivoclar Vivadent); 43 PLVs were fabricated from feldspathic porcelain (Creation, Jensen Industries). Five hundred fifty-two veneers were bonded to teeth with a marginal finishing line on the enamel, and 28 had preparations on the dentin margin. Four hundred sixty-seven veneers were bonded to teeth with intraenamel preparations; 113 veneers were bonded to teeth with dentin exposure preparations. The following products were used as cementation materials for the laminate veneers: Variolink II (Ivoclar Vivadent), 3M Opal (3M ESPE), Herculite (Heraeus Kulzer), Variolink Veneer (Ivoclar Vivadent), and Bisco Choice (Bisco Dental Products). The light-curing unit used was Optilux 501 (Kerr). Procedures and techniques for adhesive cementation followed the manufacturers' recommendations.

The following data were analyzed from clinical forms: depth of preparation (intraenamel or dentin exposure), preparation margin (enamel or dentin), coronal crown lengthening, apical crown lengthening, crowding, diastema, discoloration, presence of restoration, abrasion, and attrition.

Fig 2 *Final smile after bonding.*

Fig 3 *Postoperative clinical situation after 2 years showing ideal soft tissue health around the margins. No chipping or debonding was noted.*

Three blinded examiners independently assessed veneer failures. Pathologic gingival recession, unacceptable color match, ceramic fracture or chipping, debonding, microleakage, secondary caries, sensitivity, unacceptable marginal adaptation, and postoperative root canal treatment were all considered failures even if reparable. The most dramatic outcome was considered when two different failures occurred in the same tooth. Survival was considered when no complications were observed in follow-up examinations.

Descriptive statistics were undertaken to characterize the frequency distribution of PLVs in relation to veneer failure, type of preparation (depth and margin), crown lengthening, diastema, crowding, discoloration, presence of restoration, abrasion, and attrition.

Survival time was defined as the period between restoration cementation and when the veneer presented any clinical problem. Kaplan-Meier survival curves were plotted to analyze PLV failure, and the log-rank test was conducted to identify variables associated with PLV failure over time.[23] A multivariable analysis was performed using the Cox proportional hazards regression model with backward stepwise variable selection to determine which aforementioned variables could predict PLV failure.[24] The α level for rejection of the null hypothesis was set at 5% for all tests. SPSS software (version 19.0, IBM) was used for statistical analysis.

Results

Five hundred eighty PLVs were placed in 66 patients over a 12-year period, with a mean follow-up of 4.6 ± 2.2 years for failed PLVs and 6.1 ± 2.7 years for successful PLVs.

Forty-two laminate veneers failed (7.2%) in 23 patients (7 men, 16 women). Of these failed veneers, 20 (48%) fractured, 12 (28%) debonded, 7 (17%) showed microleakage, and 3 (7%) presented secondary caries, sensitivity, or indications for root canal treatment (Figs 4 and 5). When the preparations were limited to the enamel (preparation depth and margins in enamel), no debonding or microleakage was observed.

There was a significant association between failure and the limits of the preparation margin ($P < .001$) Moreover, the difference in failure rates between intraenamel and dentin-exposed veneers was statistically significant ($P < .001$) (Table 1).

Kaplan-Meier analysis showed overall cumulative 6- and 12-year survival rates of 92% (standard error [SE], 1%) and 86% (SE, 3%), respectively (Fig 6). Cumulative survival curves for preparation margin and depth showed a high success rate over 12 years when the margin and preparation depth were in the enamel. A survival rate of 99% (SE, 1%) was observed for veneers with preparations confined to the enamel and 94% (SE, 2%) for veneers with enamel only at the margins (Figs 7a and 7b).

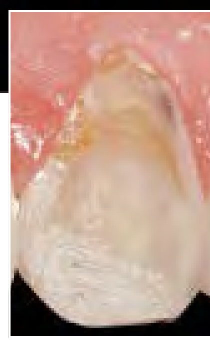



Fig 4 *Veneer failure. Incisal chipping was noted at the maxillary left central incisor and right canine. Cervical chipping and marginal leakage were noted at the left canine. (inset) After removing the veneer at the left canine, the preparations showed excessive reduction on the middle and cervical thirds with dentin exposure.*

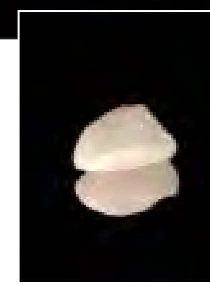



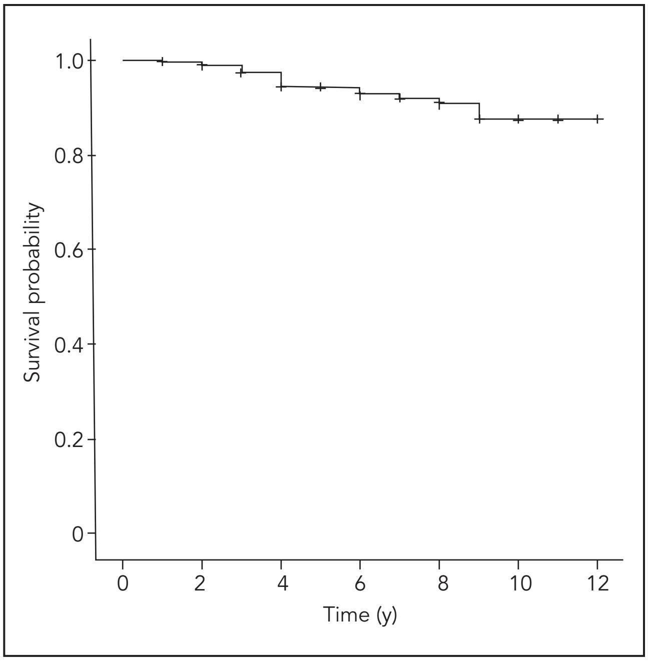
Fig 5 *Veneer failure. Complete debonding of the veneer at the maxillary left lateral incisor site was noted. Considerable misfit with marginal leakage was noted at the left central incisor and canine sites. (inset) The debonded veneer with part of the cement attached. Considerable dentin exposure was observed on the prepared lateral incisor.*

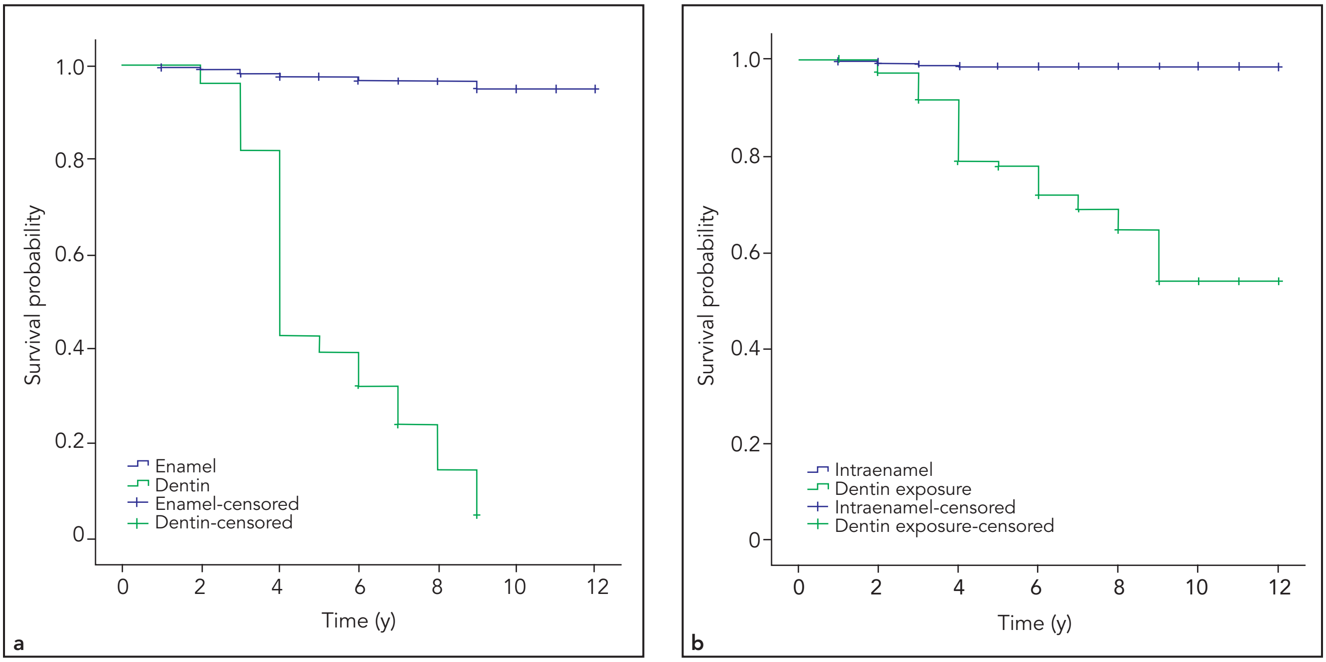
Table 1 Distribution of failed veneers according to the clinical parameters investigated

		Failure		
	n	n	%	*P**
Preparation margin				
Enamel	552	17	3.1	< .001
Dentin	28	25	89.3	
Preparation depth				
Intraenamel	467	6	1.3	< .001
Dentin exposure	113	36	31.9	
Crown lengthening				
Coronally lengthened	261	24	9.2	.13
Not lengthened	319	18	5.6	
Apically lengthened	44	1	2.3	.13
Not lengthened	536	41	7.6	
Preoperative condition				
Discoloration present	335	18	5.4	.38
Not present	245	24	9.8	
Crowding present	61	8	13.1	.03
Not present	519	34	6.6	
Abrasion present	292	23	7.9	.57
Not present	288	19	6.6	
Restoration present	94	3	3.2	.13
Not present	486	39	8.0	
Diastema present	63	6	9.5	.69
Not present	517	36	7.0	
Attrition present	51	6	11.8	.38
Not present	529	36	6.8	

*Log-rank test.

Fig 6 *Kaplan-Meier cumulative survival curve for the 580 PLVs.*





Figs 7a and 7b *Kaplan-Meier cumulative survival curves for* (a) *preparation margin and* (b) *preparation depth.*

Univariate analyses (log-rank test) showed significant differences in survival curves between the preparation margin (enamel or dentin; *P* < .001) and preparation depth (intraenamel or dentin exposure; *P* < .001) and a marginal difference between crowded and uncrowded teeth (*P* = .03).

In the final Cox model, preparation with dentin exposure and dentin margins remained significant predictors of PLV failure. Also, crowding showed a statistically significant association with coronal crown lengthening that increased the chance of PLV failure by 2.3× (95% confidence interval [CI], 1.2 to 4.3; *P* = .009).

Table 2 Cox regression model for veneer failure

	HR	95% CI Lower	95% CI Upper	*P*
Initial model				< .001
Preparation margin (dentin)	10.97	5.06	23.78	< .001
Preparation depth (dentin exposure)	12.56	4.68	33.69	.642
Discoloration	0.85	0.42	1.70	.815
Crowding	1.12	0.44	2.85	.461
Abrasion	1.36	0.60	3.08	.230
Restoration	0.47	0.14	1.62	.011
Diastema	3.80	1.36	10.64	.040
Crown lengthening coronally	2.04	1.03	4.01	.132
Crown lengthening apically	0.19	0.02	1.64	.831
Attrition	1.11	0.43	2.83	
Final model				
Preparation margin (dentin)	10.48	5.13	21.40	< .001
Preparation depth (dentin exposure)	10.26	3.90	27.01	< .001
Crown lengthening coronally	2.31	1.24	4.32	.009

HR = hazard ratio; CI = confidence interval.

Thus, PLVs bonded to dentin had a 10.3× greater risk of failure than PLVs bonded to enamel (95% CI, 3.9 to 27; $P < .001$). Furthermore, PLVs bonded to teeth with preparation margins in dentin were 10.5× more likely to fail than PLVs bonded to enamel margins (95% CI, 5.1 to 21.4; $P < .001$) (Table 2).

Discussion

Since the introduction of PLVs in the 1980s, the physical properties of the materials and bonding systems used have vastly improved, which has greatly increased the success rate of this treatment. Researchers have investigated why some PLV failures continue to occur. Recent concerns include early failures resulting from incorrect treatment planning and esthetic failures from microleakage at the tooth–porcelain margin interface.[1]

The results of this study showed that the most common failures were fracture and debonding, confirming previous findings.[10–12,21] This means that despite major advances in materials and techniques, other clinical factors may be responsible for failures. Occlusal factors and features related to the tooth-cement-ceramic interface have been cited most in the literature.[11–13,18,19,21,22]

Adhesive or cohesive failures may cause fractures in which part of the PLV may be broken while the bonded portion remains intact. A fracture from adhesive failure usually appears after external stimulus and presents with a large portion of the restoration fractured and a smaller piece adhered to the tooth, while a fracture from cohesive failure shows a small piece of the PLV chipped off, leaving most of the PLV intact.[1] In both cases, unfavorable occlusion and parafunction play an important role. Previous studies have also related bruxism with a high fracture rate of PLVs.[8,21,25] However, in this study, a significant association could not be observed between bruxism (attrition) and failure.

Several reports have demonstrated that fractures may occur if the surface of the tooth has not been prepared sufficiently to create space for the PLV buildup.[1–4] On the other hand, deep preparations that expose dentin will increase the risk of microleakage and adhesive fractures.[10,12,13] There was a significant association between failure and preparation depth and margin ($P < .001$).

Previous studies have reported that debonding and microleakage are more pronounced when the preparation is in the dentin.[8,10,12,13] Confirming this result, in 100% of PLVs in this study in which microleakage, secondary caries, postoperative sensitivity, or debonding occurred, the tooth substrate was dentin. Polymerization shrinkage of the luting composite and the difference in thermal expansion coefficients between the tooth and porcelain have been the factors most cited for the occurrence of microleakage.[1,8,13,18]

A thorough check of the prostheses was made, and APT restorations were used to guide tooth preparation so that minimal enamel was removed. However, there are clinical situations in which exposure of the dentin in the preparation for PLVs is inevitable because of greater tooth reduction performed by professionals (in stained, buccally positioned, or crowded teeth) or natural wear of the enamel (abrasion and attrition). In such cases, bleaching and orthodontic tooth movement were performed to minimize the tooth preparation. Working within these protocols, discoloration and abrasion/attrition did not significantly influence the failure rates of PLVs.

A cumulative survival rate of 92% at 6 years suggests that PLVs represent an effective procedure for conservative and esthetic treatment, and a survival rate of 86% at 12 years compares favorably with other clinical studies[10,11,21] that reported high survival rates for PLVs (see Fig 6).

Laboratory studies have evaluated incisal coverage in relation to longevity and failure. Tooth preparation without incisal overlap (window preparation) showed better results than preparation with incisal edge overlap.[26] If incisal coverage is indicated for occlusal or esthetic reasons, in vitro studies have shown that a palatal chamfer margin design increased the fatigue failure cycle count[27] and failure load.[28] However, there is no consensus in the literature as to whether an incisal edge should be included in the preparation.[29] On the other hand, a clinical study[12] demonstrated that an overlapped incisal edge had a significantly positive effect on the survival rate. Another study[30] reported that no significant differences between incisal porcelain coverage or uncovered incisal edges could be observed. In the present study, after 12 years of observations, incisal coverage with coronal crown lengthening showed a significant influence on failure rates (see Table 2).

Previous research[19] reported fractures of veneers bonded on teeth with large composite resin restorations. The lower adhesion to the large composite resin and exposed dentin surfaces was considered the most likely reason for these failures. The authors therefore concluded that the presence of composite resin restorations had a negative influence on the overall clinical performance but did not increase the loss of veneers. This finding is not in agreement with the present study, in which among the 42 failures, only 3 occurred in teeth with restorations, and no significant association could be observed between failure and presence of a restoration.

The relationship between diastema and failures was also tested. One of the most critical areas in diastema closure is the proximogingival area because the preparation should be extended to intrasulcular areas. The depth and palatal extension of the area will be dictated by the size of the spacing and the position and volume of the papilla.[1] In some cases, crown lengthening was executed apically to supply pleasing proportions within the tooth itself and among the teeth. Also, the basic principles of bone and soft tissue relationships were carefully followed, and excellent communication between the dentist and specialist concerning the repositioning of the zenith points relative to the new PLV positions was established. By taking these precautions, the success rate was high, and no significant association could be observed between failure and diastema or between failure and apical crown lengthening.

Patient characteristics collected from the current database turned out to be potential negative prognostic factors, some of which (preparation depth and margin) were demonstrated to be such in earlier studies.[10,12,13,20] However, other features that could be complicating factors (attrition, abrasion, filling, discoloration, diastema, and apical crown lengthening) showed no significant relationship with failure.

Many factors act on the teeth and restorations, and clinically, it is almost impossible to separate the causative factor of failure. Only when each factor was assessed separately could it be seen whether it really contributed to the failure. Some factors showed a numeric causal trend, which was not confirmed statistically. It can therefore be stated that causative factors represent clinical challenges, which if neglected may determine the onset of failures. Clinical experience and scientific background combined with a precise technique may be the differential factor for professionals to be able to identify and overcome the factors that influence the occurrence of failures.

Clinical experience and appropriate preparation design have already been associated with greater veneer survival in the literature.[31] Some publications have demonstrated that a major component of dentists' work is restoration of previously restored teeth. In clinical trials, proficient operators are often selected to participate, and operator influence is usually examined secondarily.[32]

The results of this study and other reports in the literature point to the importance of planning and preparation technique on the success of PLVs. To reduce the risk of failure, it has been recommended to meticulously plan the case, perform a guided preparation, and preserve the enamel. The APT technique allows predictability of results and better communication with the dental lab and patient. In the future, even more conservative preparation, mathematic tooth reductions calculated to achieve the final color desired in accordance with the ceramic system used, and planning of custom PLVs according to visagism concepts are objectives to be achieved.

Conclusions

The results obtained in this clinical retrospective study revealed no influence of apical crown lengthening, restoration, diastema, discoloration, abrasion, or attrition on failure rates. However, a significant association was observed between failure and both coronal crown lengthening and tooth preparation with dentin exposure and dentin margins. The long-term survival rates significantly increased when intraenamel preparations were used.

Acknowledgment

The authors reported no conflicts of interest related to this study.

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