Clinical Performance of Porcelain Laminate Veneers for Up to 20 Years

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Purpose: The aim of this clinical retrospective study was to evaluate the clinical quality, success rate, and estimated survival rate of anterior veneers made of silicate glass-ceramic in a long-term analysis of up to 20 years. ***Materials and Methods:*** Anterior teeth in the maxillae and mandibles of 84 patients (38 men, 46 women) were restored with 318 porcelain veneer restorations between 1987 and 2009 at the Medical University Innsbruck, Innsbruck, Austria. Clinical examination was performed during patients' regularly scheduled maintenance appointments. Esthetic match, porcelain surface, marginal discoloration, and integrity were evaluated following modified California Dental Association/Ryge criteria. Veneer failures and reasons for failure were recorded. The study population included 42 (50.0%) patients diagnosed with bruxism and 23 (27.38%) smokers. The success rate was determined using Kaplan-Meier survival analysis. ***Results:*** The mean observation time was 118 ± 63 months. Twenty-nine failures (absolute: 82.76%, relative: 17.24%) were recorded. The main reason for failure was fracture of the ceramic (44.83%). The estimated survival rate was 94.4% after 5 years, 93.5% at 10 years, and 82.93% at 20 years. Nonvital teeth showed a significantly higher failure risk ($P = .0012$). There was a 7.7-times greater risk of failure associated with existing parafunction (bruxism, $P = .0004$). Marginal discoloration was significantly greater in smokers ($P \leq .01$). ***Conclusion:*** Porcelain laminate veneers offer a predictable and successful restoration with an estimated survival probability of 93.5% over 10 years. Significantly increased failure rates were associated with bruxism and nonvital teeth, and marginal discoloration was worse in patients who smoked. *Int J Prosthodont 2012;25:79–85.*

The esthetic appeal, durability, and biocompatibility of porcelain laminate veneers (PLVs) have made them an established option for restoring anterior teeth for almost three decades. The technique was first introduced and described by Dr Charles Pincus in Hollywood in 1938 to enhance actors' appearances for movie close-ups.[1] He attached thin veneers temporarily using denture adhesive powder.

The discoveries of the acid-etch technique, composite luting resin, and silane-coupling agents have contributed to the success all-ceramic veneers enjoy today. Additionally, the problems of acrylic and composite resin as veneering materials have also encouraged the use of all-ceramic veneers.

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Today, PLVs are mainly used to optimize tooth form and position, close diastemata, replace discolored or unesthetic composite resin restorations, restore teeth with incisal abrasions or tooth erosion, and mask or reduce tooth discoloration.[2,3] They are a valid alternative to complete-coverage restorations since they avoid aggressive dental preparation, thus maintaining tooth structure.[4] Currently, four groups of ceramic systems are used for veneers: feldspathic porcelain baked by using the traditional powder-water-slurry method, castable glass-ceramic, heat-pressed ceramic, and computer-aided design/computer-assisted manufacturing.[5]

Numerous studies have demonstrated success with porcelain veneer restorations.[6–8] However, long-term analyses are rare.[9] Although PLVs are an accepted treatment in the restoration of anterior teeth, many authors suggest that parafunction (bruxism) constitutes a contraindication to adhesive restorations since veneers have an increased failure rate.[10,11] Bruxism is a parafunctional rhythmic activity in which patients clench or grind their teeth during the day or at night.[12] Bruxism was classified by Ramfjord and Ash into two categories: the centric category with vertical loading during waking hours

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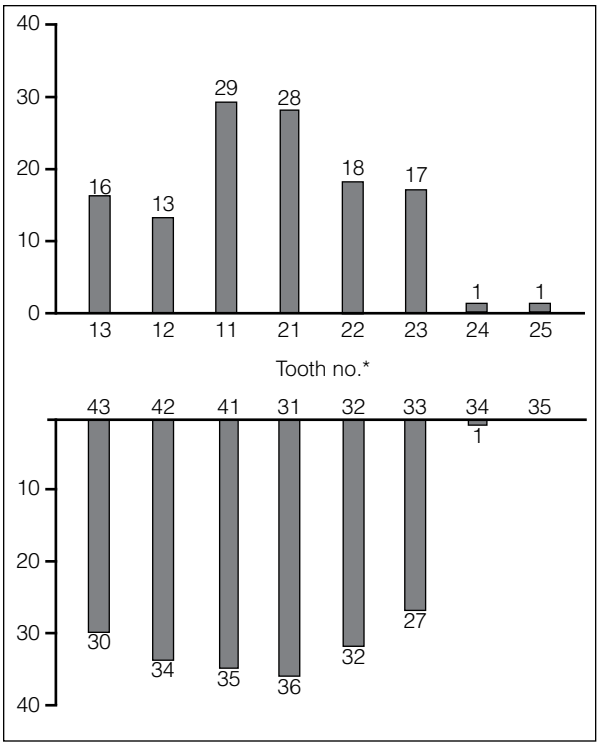


Fig 1 Distribution of veneer restorations. *FDI tooth-numbering system.

and the excentric category with grinding behavior into lateral excursion while sleeping.[13] The etiology of bruxism still remains unclear, but most current theories lend great importance to psychologic factors and stress.[14,15] The success rate of PLVs in patients with parafunction is reduced but can be increased if parafunctional activities are controlled.[16]

The purpose of the present retrospective clinical study was to evaluate the clinical quality, success rate, and estimated survival rate of anterior PLVs made of silicate ceramics in a long-term analysis of up to 20 years. Additionally, risk factors for PLV failure were evaluated.

Materials and Methods

Eighty-four patients (38 men, 46 women) were examined during their regularly scheduled maintenance appointments at the Department of Restorative and Prosthetic Dentistry, Innsbruck Medical University, Innsbruck, Austria, between March 2010 and July 2010. The clinical procedure and evaluation were similar to those described previously.[17] Half of the patient group self-reported or were diagnosed with bruxism (n = 42 patients). The clinical diagnosis was made by clinical inspection of the teeth if the consequences of clenching or grinding activities were visible in the dentition and consistent with a bruxing habit. The observation of tooth wear or spots on restorations was performed on a tooth-by-tooth basis in relation to the patients' age and coarseness of diet. Twenty-three patients reported a regular smoking habit (27.38%). A smoking history more than 2 years prior was not recorded.

Ceramic-specific and patient-specific variables were recorded before clinical examination, and esthetic match, porcelain surface, marginal discoloration, and integrity were evaluated following modified California Dental Association (CDA)/Ryge criteria.[18,19] Papilla Bleeding Index (PBI) was assessed to evaluate patients' oral hygiene.[20] Veneer failures and reasons for failure were recorded. Additionally, patients were asked about their satisfaction with the veneer restoration and if they would undergo treatment again. Only anterior veneers were included in this study.

The veneer sample consisted of 318 silicate ceramic restorations placed between November 1987 and December 2009 at the Department of Restorative and Prosthetic Dentistry, Innsbruck Medical University. All veneers were performed by two associate professors using a similar clinical procedure as that reported in 1999.[5] Depending on the era, PLVs were fabricated with feldspathic porcelain, leucite heat-pressed ceramic, or lithium disilicate heat-pressed ceramic.

After cementation and finishing under 2.5× magnification, occlusion was checked carefully and adjusted as necessary to establish canine-guided dynamic occlusion.[21–23]

Statistical Analysis

Data were tabulated using Excel 2003 (Microsoft Office Excel 2003, Microsoft). Statistical analysis was performed using SAS 9.2 software (SAS Institute).

The survival time was defined as the period of time starting from the successful fitting of the veneer restoration and ending when the restoration presented with an irreparable problem. Kaplan-Meier methodology was used for the calculation of the survival probabilities in this study. This nonparametric statistical technique accounts for censored observations resulting from incomplete follow-up.[24] The Cox proportional hazards model was used to study the influence of various risk factors for veneer failure. Since many patients had more than one veneer restoration, robust standard errors were computed using the methods of Lin and Wei.[25] Because of the small number of events, only univariate models are presented.

Associations with binomial outcomes were assessed using logistic regression incorporating generalized estimating equations.[26] This process

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Table 1 Frequency Distribution of Bonding System and Type of Cement Used*

	Cement									
	Optec Cement		Dual Cement		3M cement		Variolink high-viscosity		Total	
Bonding	n	%	n	%	n	%	n	%	n	%
No dentin bonding	13	4.1	12	3.8	2	0.6	11	3.5	38	12.0
Syntac Classic	6	1.9	0	0.0	3	0.4	29	9.1	38	12.0
Optibond FI	25	7.9	2	0.6	0	0.0	215	67.6	242	76.1
Total	44	13.8	14	4.4	5	1.6	255	80.2	318	100.0

*Optec Cement, Jeneric/Pentron; Dual Cement, Ivoclar Vivadent; 3M Cement, 3M ESPE; Variolink high-viscosity, Ivoclar Vivadent; Syntac Classic, Ivoclar Vivadent; Optibond FI, Kerr.

estimated a correlation between observations from the same patient. The level of significance was established at $P \leq .05$.

Results

The mean observation period was 118 ± 63 months for the 318 restored teeth, with 152 restorations observed over 10 years, 75 restorations observed over 15 years, and 3 restorations observed over 20 years of service. The mean age of patients at the time of cementation was 44.42 ± 13.14 years. The distribution of the restored teeth is presented in Fig 1. The frequency distribution of the ceramic material, bonding system, and type of cement used is presented in Table 1.

During the clinical examination undertaken between March and July 2010, 9 veneer restorations were rated as failures. The Kaplan-Meier survival analysis of the 318 veneer restorations with 29 failures evaluated is shown in Fig 2. The estimated survival rate was 94.4% after 5 years, 94.1% at 8 years, 93.5% at 10 years, 85.74% at 15 years, and 82.93% at 20 years.

All together in this period, 298 restorations were examined clinically. The results of the clinical evaluation of all veneers using modified Ryge criteria are presented in Table 2. The entire study population contained 318 veneer restorations since 20 veneer failures occurred before the evaluation in 2010. The patient-specific and ceramic-specific data were taken from patients' charts and a ceramic database. Data concerning the type of failure and PBI were present, but not clinical data using modified Ryge criteria. For this reason, only 298 clinical evaluations are presented in Table 2, with the results of the CDA/Ryge classification. Of the total veneer group, 97% were rated satisfactory.

Unsatisfactory ratings (n = 9) were noted for the category porcelain surface; all 9 veneers were rated Charlie. No Delta ratings were found. The defined categories were rated as follows: esthetic match, Alpha (263, 88%) and Bravo (12, 12%); porcelain surface, Alpha (222, 74.5%) and Bravo (67, 22.5%); marginal discoloration, Alpha (234.5, 78.7%) and Bravo (63.5, 21.3%); and marginal integrity, Alpha (270.25, 90.7%) and Bravo (27.75, 9.3%). Especially for the category marginal discoloration, the lingual aspect of the veneer restoration was only rated Alpha (219, 73.4.%) and Bravo (79, 26.5%).

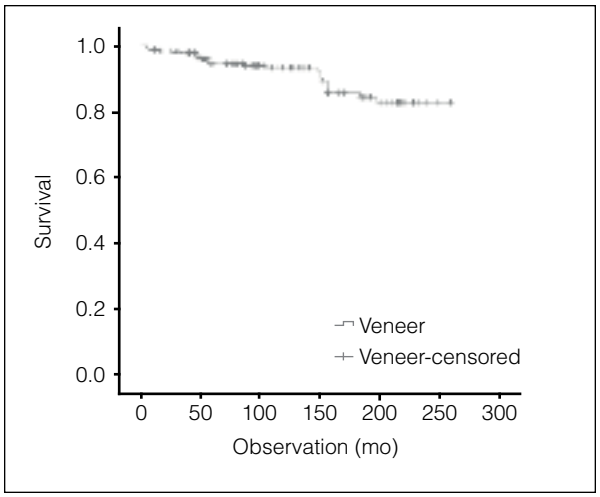


Fig 2 Overall veneer survival estimates.

Marginal discoloration was significantly higher in patients who smoked at all aspects of the ceramic veneers: buccal, $P = .0014$; mesial, $P = .0044$; distal, $P < .0001$; and lingual, $P = .0053$. A detailed association between smoking and marginal discoloration is presented in Table 3.

Papillary bleeding after cautious probing of the sulcus was present in 82 (25.8%) restored teeth. No statistical dependence of PBI was found for the type of cement used or for the rating of the marginal integrity.

In summary, 29 veneer failures were recorded. The overview of the failure characteristics for absolute (82.76%) and relative (17.24%) failures is presented in Table 4. The most frequent reason for failure was fracture of the ceramic (44.83%) (Fig 3). The second most frequent reason for failure was cracks in the veneer ceramic (n = 8, 27.59%) (Fig 4). Chipping (n = 3) and debonding (n = 3) occurred in approximately 10% of all failure cases.

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Table 2 Clinical Evaluation of All Veneers Using Modified Ryge Criteria[18,19]

	Alpha		Bravo		Charlie		Delta	
Parameter	n	%	n	%	n	%	n	%
Esthetic match	263	88.0	12	12.0	0	0.0	0	0.0
Porcelain surface	222	74.5	67	22.5	9	3.0	0	0.0
Marginal discoloration								
Buccal	229	76.8	69	23.1	0	0.0	0	0.0
Mesial	239	80.2	59	19.8	0	0.0	0	0.0
Distal	251	84.2	47	15.8	0	0.0	0	0.0
Lingual	219	73.4	79	26.5	0	0.0	0	0.0
Mean	234.5	78.7	63.5	21.3	0	0.0	0	0.0
Marginal integrity								
Buccal	255	85.6	43	14.4	0	0.0	0	0.0
Mesial	289	97.0	9	3.0	0	0.0	0	0.0
Distal	286	96.0	12	4.0	0	0.0	0	0.0
Lingual	251	84.2	47	15.8	0	0.0	0	0.0
Mean	270.3	90.7	27.8	9.3	0	0.0	0	0.0

Alpha and Bravo = satisfactory; Charlie and Delta = unsatisfactory.

Table 3 Association of Smoking with Marginal Discoloration

	No smoking				Smoking				
	Alpha		Bravo		Alpha		Bravo		
	n	% of 212	n	% of 212	n	% of 86	n	% of 86	*P*
Buccal	180	84.9	32	15.1	49	57.0	37	43.0	.0014*
Mesial	186	87.7	26	12.3	53	61.6	33	38.4	.0044*
Distal	196	92.5	16	7.5	55	64.0	31	36.0	< .0001***
Lingual	173	81.6	39	18.4	46	53.5	40	46.5	.0053*

*P < .01.
***P < .001.

Half of the patient population (n = 42) self-reported or were diagnosed as bruxers. Statistical analysis revealed a significantly higher failure rate for veneer restorations in patients who were bruxers. The hazard ratio for bruxism was 7.74. Eleven (3.46%) abutment teeth were nonvital and received endodontic therapy before ceramic treatment, and 8 (2.51%) had root canal treatment after cementation. The nonvital abutment teeth showed a significantly higher failure risk with a hazard ratio of 0.2 (P = .0012) (Table 5). No significant differences were found for the risk of failure between veneers that had endodontic treatment prior to or after ceramic restoration (P = .72) or between the maxilla and mandible (P = .61).

Of the four responses given to self-rating patient satisfaction (excellent, good, medium, or none), no one rated satisfaction as medium or none. Seventy-six patients (92.9%) rated satisfaction as excellent, and six patients (7.1%) rated it as good. All of the patients, even those who had veneer failures, regarded the PLVs as an ideal type of dental restoration and would bear the ceramic procedure, time, and costs again.

Discussion

This retrospective clinical study evaluated the clinical quality, success rate, and estimated survival rates of anterior PLVs made of silicate ceramic in a long-term analysis of up to 20 years. Additionally, risk factors for PLV failure were evaluated. After a mean observation period of 118 ± 63 months, 29 failures occurred.

Many authors state that fractures are the most frequent cause of clinical failure of ceramic veneer restorations, as seen in this study.[9,27] In a previous report,[17] a significant difference between luting agents was observed, but after evaluating the veneer data, no significant differences in the use of different bonding and cementation materials were observed and determined as a predictor. A significantly higher risk of failure was observed in this study in restorations on nonvital teeth (P = .0012) and patients with parafunction (P = .0004). Occlusal forces can increase microleakage and gap formation at the cervical margin and may impair the retention of the restoration, which may lead to cracks and fractures in

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Table 4 Overview of Failure Characteristics

	Absolute failure		Relative failure		Total	
	n	%	n	%	N	%
Fracture of the ceramic	13	44.83	0	0.00	13	44.83
Caries	0	0.00	1	3.45	1	3.45
Crack in the ceramic	6	20.69	2	6.90	8	27.59
Chipping	2	6.90	1	3.45	3	10.34
Debonding	2	6.90	1	3.45	3	10.34
New restoration after endodontic treatment	1	3.45	0	0.00	1	3.45
Total	24	82.76	5	17.24	29	100.00



Fig 3 Palatinal fracture of ceramic in a nonvital tooth.



Fig 4 Crack in the ceramic and marginal discoloration resulting from a smoking habit.

Table 5 Univariate Cox Models for Veneer Failure

Parameter	Hazard ratio (95% confidence interval)	*P*
Maxilla (vs mandible)	1.261 (0.517–3.078)	.6100
Nonvital (vs vital)	0.211 (0.083–0.540)	.0012*
Bruxism (vs no bruxism)	7.744 (2.503–23.954)	.0004***

*$P < .01$.
***$P < .001$.

the restoration.[28,29] The determined risk was almost 8 times higher for failure in bruxing patients than in patients without a bruxing habit. This is more than 3 times higher than that for all restorations observed in general.[17] Parafunction may continue after careful restoration,[30] even after specific guidelines are established with the patient. Therefore, after placing the ceramic restorations, patients who were bruxers were provided with hard acrylic resin occlusal guards to protect the definitive restorations during bruxing episodes.

Patients were informed that there was still a risk of ceramic fracture if compliance with using the occlusal guard was inadequate. No guards would have worsened the results, but not all guards were worn, even after careful explanation. But the results of this clinical study suggest that even when patients with parafunction are selected for esthetic veneer restoration, the overall outcome and clinical acceptance are satisfactory. However, before preparation, patients should be informed about the almost 8-times higher risk of failure resulting from bruxism as motivation to wear the guard during bruxing episodes. Patient satisfaction was encouraging, even in patients who had failures.

This study showed an estimated survival rate of 94.4% after 5 years of service. This concurs with the study by Layton and Walton (96% ± 1% at 5 to 6 years),[8] the 5-year clinical results of Peumans et al (93%),[27] the meta-analysis by Kreulen et al (> 90% for 3 years),[31] and a former veneer study at the Innsbruck clinic (97%).[7] Shaini et al[32] evaluated 372 PLVs that were fit to defective and discolored teeth in 102 patients. The restorations showed less successful survival rates, but the conditions were different and should not be compared with actual veneer data because 90% of these veneers were placed on unprepared teeth.[32] Proper tooth preparation is important for the long-term success of ceramic restorations.[33]

The estimated survival of veneers in this study at 15 years was 85.74%. Layton and Walton showed a cumulative survival rate of 73% ± 16% at 15 to 16 years,[8] but they pointed out that there was a marked drop in survival between 13 and 16 years because of the death of one patient and the combination of a low

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veneer number in this period, resulting in less power of the sample size. In the present study, at 15 years, 75 veneers were still in service, thus the estimated survival rate of 85.74% seems reasonable. However, at 12 to 13 years, Layton and Walton[8] reported a success rate of 91% ± 3%, which concurs with the present observations where the estimated success rate dipped under 90% after 12.86 years.

The present results differ greatly from the long-term analysis of Friedman,[9] whose results from an up to 15-year review of porcelain veneers show an aggregate failure rate of approximately 7% in 3,500 restorations. However, the study mentioned that not all restorations observed had been in place for 15 years. No mean observation time of the veneer restoration is mentioned in this study. For this reason, the authors cannot compare estimated success rates at 15 years.

The clinical outcome showed marginal discoloration in 21.3% of restorations. This result is comparable to other studies that found marginal discoloration in 18%, 22%, and 25% of restorations.[7,34,35] This study additionally revealed significantly higher marginal discoloration in patients who smoked at all aspects of the ceramic veneers compared to nonsmoking patients. Smoking patients receiving PLVs should be informed before preparation about the higher risk of marginal discoloration and staining of the teeth. In this study, teeth were repositioned or new anterior guidance and esthetics were established in patients with and without parafunction. In contrast to other veneer studies, more restorations were performed in the mandible,[3] often to establish new anterior guidance with an increase of the vertical dimension in full-mouth restorations. After comparison, the data on veneers placed in the maxilla or mandible were not found to be significant. The sample size was too small to compare the position of the veneer in the mouth. Higher porcelain veneer failure rates have often been observed when the gingival margin is located on dentin. Ideally, all veneer margins should be on enamel. When cervical margins had to be defined on dentin, the authors used highly filled, viscous resin cements and a three-step bonding technique (etch, prime, and bond) to achieve the greatest longevity.[7]

Bearing in mind that 12% of the evaluated 318 veneers were cemented without dentin bonding, a better prognosis can be anticipated for PLVs bonded with dentin bonding systems, which offer a superior adhesive technology that might reduce failure risk.

The present study had some limitations: The 318 veneers were placed over a long period of up to 20 years, not simultaneously, and the different materials used could not be compared statistically with each other because they varied in number. In the future, the preparation design of the evaluated veneers and the chosen preparation margin should be evaluated additionally. Furthermore, all-ceramic preparations were performed under university conditions by only two experienced dentists and with patients who had to be free of active gingival and periodontal inflammation prior to ceramic treatment and with a focus on careful occlusal adjustment. A more compromised oral environment may have produced different results. The observed risk factors (parafunction and nonvital abutment teeth) need to be confirmed in studies with a more rigorous design. Nevertheless, this study presents an up to 20-year analysis with good clinical outcome results with an estimated survival rate of 90% at 12 to 13 years.

Conclusion

This study evaluated 318 veneer restorations placed in 84 patients. The mean observation time was 118.72 months. Within the limitations of this study, the following conclusions can be drawn:

- PLVs offer a predictable, conservative, and highly successful restoration.
- The estimated survival probability at 10 years was 93.5%.
- The main reason for failure was fracture of the ceramic.
- Increased failure rates were associated with parafunction (bruxism) and nonvital abutment teeth.
- No significant differences were found for the risk of failure of the veneers between the maxilla and mandible.
- Marginal discoloration is significantly worse in patients who smoke.

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